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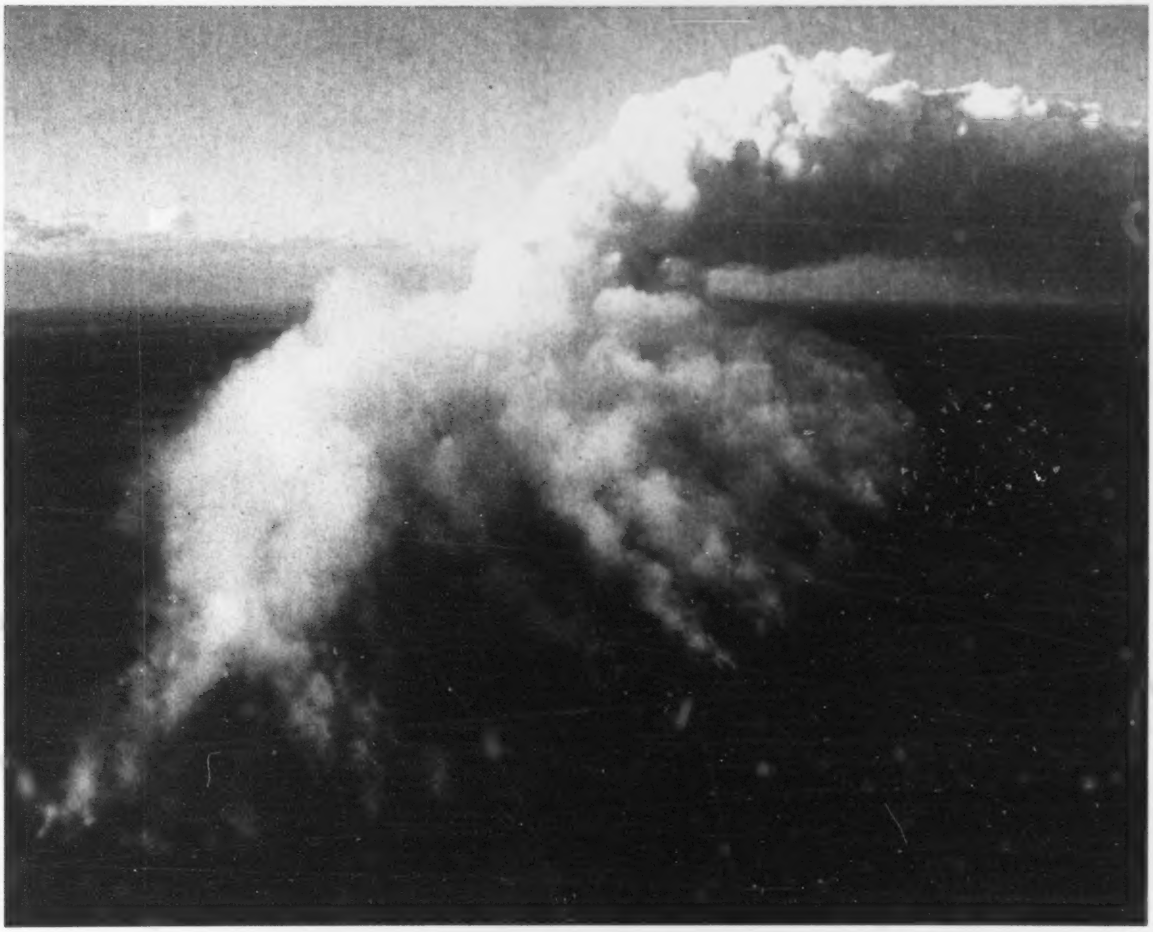

Ontario

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Red Lake 084 of 2011: A Reconnaissance Survey of a Large Boreal Wildfire

Ismail Baysal[1,2], Marc Ouellette[1*], and Jeff Antoszek[3]

[1]Ontario Forest Research Institute, Ontario Ministry of Natural Resources, 1235 Queen St. E., Sault Ste. Marie, ON Canada, *corresponding author

[2]KTU Orman Fakultesi, Orman Muhendisligi, Orman Entomolojisi ve Koruma Anabilium Dali, 61080 Trabzon, Turkey

[3]Aviation, Forest Fire and Emergency Services, Ontario Ministry of Natural Resources, 95 Ghost Lake Rd., Dryden, ON Canada

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Ontario Forest Research Institute
Ontario Ministry of Natural Resources
1235 Queen Street East
Sault Ste. Marie, Ontario
Canada P6A 2E5

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Abstract

The 54,000 ha fire, RED-084, occurred in an area previously undisturbed by forest harvest and by only a small wildfire in 1999. It was caused by lightning and burned for over three weeks despite the many efforts to control its spread. This fire created a highly heterogeneous post-burn landscape with large patches of varying degrees of fire severity as well as numerous unburned residual patches of many shapes, sizes, and locations. In this report, we present photographic evidence of these patterns based on observations during the burn, and a survey of post-fire patterns from both the air and on the ground, conducted within a few weeks of the fire being declared under control. We also provide a compilation of many databases of weather and pre-burn forest cover including fuel type distribution and spatial-temporal progression of fire.

Resumé

Incendie Red Lake 084 de 2011 : reconnaissance d'un vaste incendie dans une forêt boréale

L'incendie qui a ravagé 54 000 hectares (RED-084) a eu lieu à un endroit qui n'avait pas été touché par l'exploitation forestière et n'avait subi auparavant (en 1999) qu'un petit incendie. Il a été causé par des éclairs. Il a duré plus de trois semaines, malgré les nombreux efforts déployés pour limiter sa propagation. Cet incendie a laissé un paysage très hétérogène comprenant de vastes parcelles où l'intensité du feu a été plus ou moins forte, ainsi qu'un grand nombre de parcelles non brûlées à divers endroits, qui sont de dimensions et de formes très variées. Dans le présent rapport, nous présentons des photos qui illustrent ces configurations par des observations faites pendant l'incendie, ainsi qu'un relevé des configurations postincendie fait du haut des airs et au sol quelques semaines après que l'incendie a été déclaré être maîtrisé. Nous présentons aussi une compilation de maintes bases de données sur les conditions météorologiques et le couvert forestier avant l'incendie, dont la distribution du feu par types de combustible et la progression spatiotemporelle de l'incendie.

Acknowledgements

We thank the following individuals who assisted us in compiling this report: Mike St. Eloi, Mike Zastre, Joe Eder, Mike Kitney, Rob Luik, and Jim Caputo (all with the Ontario Ministry of Natural Resources; MNR), provided data and information; Harold Lohn (KaBeeLo Lodge) permitted us to land at an outpost camp during the aerial survey and Wilderness Air conducted the flight over RED-084. As well we thank MNR's Aviation, Forest Fire and Emergency Services for providing the cover photo and fire suppression images used in the report and Dave Heaman for reviewing a draft.

Contents

1.0 Introduction

As in other boreal regions in the world, periodic wildfires are responsible for maintaining a shifting spatial mosaic of ages and cover types within Ontario's boreal forest landscape. While wildfires are an integral part of boreal ecosystems, these sometimes pose a threat to anthropogenic values such as infrastructure and standing timber. This is particularly true in the dry and fire-prone northwestern Ontario, where communities, power lines, mines, and remote tourism outposts are interspersed within that vast forest landscape. Northwestern Ontario has a history of frequent wildfires, where some events are among the largest in the province (Figure 1). Consequently, this region draws a considerable amount of resources for fire management, especially fire suppression. However, the occurrence of large wildfires in northwestern Ontario has been inconsistent during the past decade (Table 1). The last fire season with considerable numbers of large wildfires in this region was in 2006, when 26 fires exceeded 1000 ha.

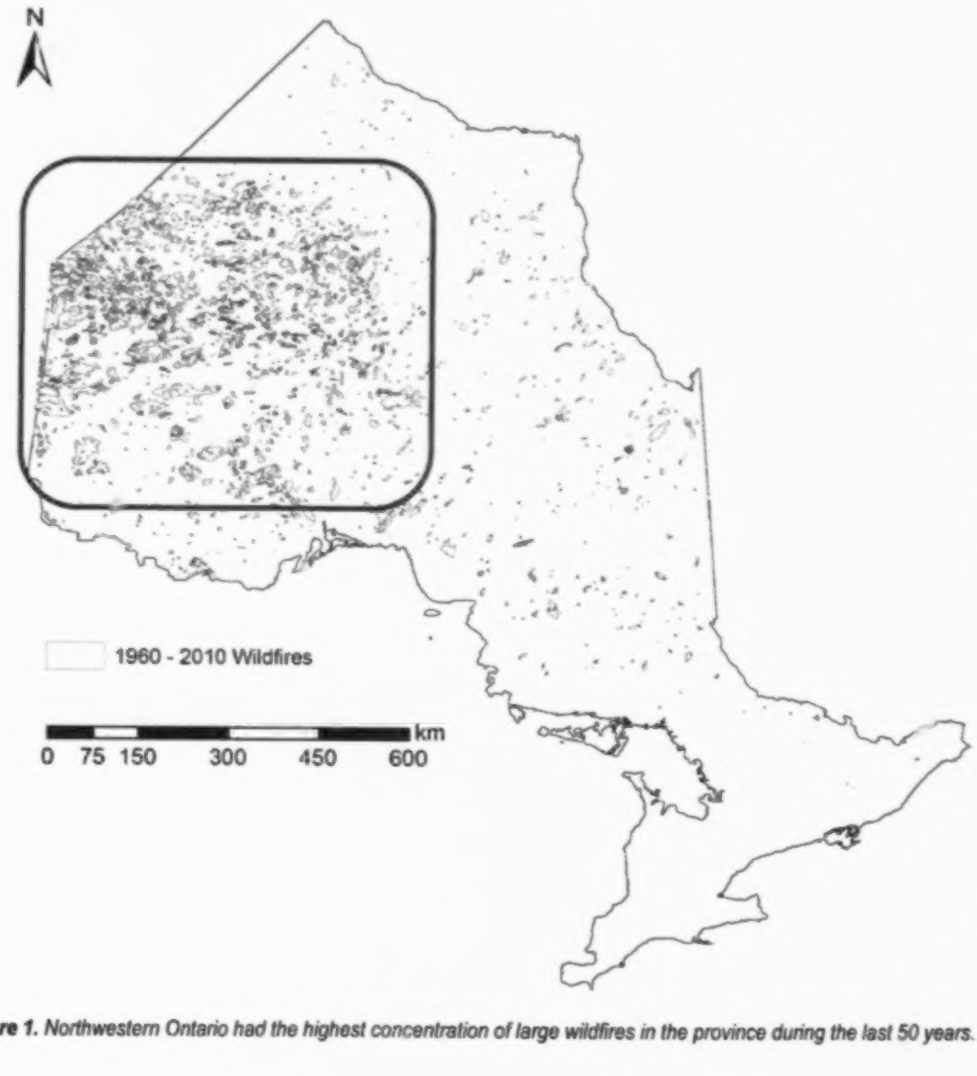


Figure 1. Northwestern Ontario had the highest concentration of large wildfires in the province during the last 50 years.

Table 1. *The number and extent of large (>1000 ha) wildfires in northwestern Ontario during 2000-2010 (DFOSS fire archives, OMNR).*

Year	Number	Extent (ha)
2000	6	8572
2001	1	2505
2002	25	175,914
2003	16	249,810
2004	1	1177
2005	6	27,497
2006	26	120,880
2007	3	31,040
2008	0	0
2009	3	5940
2010	3	7832
Total	90	631,171

The year 2011 produced an extreme fire season in Ontario, with over ten times the average burn area of the last decade.[1] Most of these fires occurred in northwestern Ontario, with 908 fires that covered over 632,000 ha (OMNR, AFFES, unpublished data, 2011). Frequent lightning storms in combination with hot, dry, and often windy weather caused extensive burns in the northern parts of the Red Lake, Sioux Lookout, and Nipigon districts and these fires destroyed large areas of standing timber and infrastructure. Furthermore, smoke emissions from the wildfires affected several settlements causing the evacuation of 4,476 people from 11 northern communities for health concerns, and in some cases due to direct fire threat. One of the largest 2011 fire events in Ontario, RED-084 was reported on July 10th, northeast of Ear Falls, and continued to burn for over a month until it stopped spreading on August 02 and was declared under control on September 03. The final area within the burn perimeter mapped by the Ministry of Natural Resources (MNR) was 54,828 ha.[2]

In this report, we describe RED-084 in detail with respect to its pre-burn characteristics, fire weather, progression of the burn through time (including observations by J. Antoszek), and immediate post-fire conditions as observed (I. Baysal and M. Ouellette) by an aerial reconnaissance survey and a ground survey of the readily accessible parts of the fire. We selected this fire because it constitutes a natural fire event: it was caused naturally (lightning); most of the area burned had not been previously harvested or altered by other means; and, despite the many efforts to suppress it, the fire continued unabated and was extinguished naturally. Such events, especially with ready accessibility, are rare and likely to provide considerable insight to natural fire processes and patterns.

[1] 2011 fire summary, Aviation, Forest Fire and Emergency Management (AFFES) http://www.mnr.gov.on.ca/en/Business/AFFM/2ColumnSubPage/STDPROD_090851.html

[2] This includes all land and water area inside the mapped fire perimeter.

2.0 Pre-Burn Forest Conditions

The disturbance history and forest cover of the area in which RED-084 burned is briefly described by way of background context for the fire event. Forest cover characteristics and prior disturbances are important because they influence the amount and condition of available fuel and thus affect fire behaviour. Pre-burn, the area was predominately undisturbed mature forest interspersed with many lakes and wetlands.

2.1 Cover types

Pre-burn forest cover was dominated by mature black spruce (*Picea mariana* [Mill.] B.S.P.) and jack pine (*Pinus banksiana* Lamb.), with small pockets of other species, including balsam fir (*Abies balsamea* [L.] Mill.) and trembling aspen (*Populus tremuloides* Michx.) (Figure 2a) (OMNR 1990, 2000). The forest in the area was mostly 80 to 120 years old, but was interspersed with small areas of older and younger stands (Figure 2b). MNR's fire records indicate that a fire had occurred in the area of the RED-084 within the recent past. This fire, RED-058, burned 5,278 ha in August of 1999 in the northwestern part of the area (OMNR fire archive). No other natural disturbances are on record for this area.

2.2 Fuel types

The most prevalent fuel types in the area were C-2 (boreal spruce) and C-3 (mature jack pine). Fuel type classifications, described in Table 2, are based on the Canadian Forest Fire Behaviour Prediction System (FBP system) (Forestry Canada Fire Danger Group 1992). The pre-fire fuel map for the area (Figure 3) was generated from the provincial fuels database (Caputo 2003), which combines current forest resource inventory (OMNR 1990, 2000) with LANDSAT data (Caputo 2003).

***Table 2**. Fuel type classes based on the FBP system (Forestry Canada Fire Danger Group 1992).*

Cover	Fuel class	Description
Conifer	C-1	Spruce-lichen woodland
	C-2	Boreal spruce
	C-3	Mature jack or lodgepole pine
	C-4	Immature jack or lodgepole pine
	C-5	Red or white pine
	C-6	Conifer plantation
Deciduous	D-1	Leafless aspen
Mixedwood	M-1	Boreal mixedwood - leafless
	M-2	Boreal mixedwood - green
	M-3	Dead balsam fir-mixedwood - leafless
	M-4	Dead balsam fir-mixedwood - green
Slash	S-1	Jack or lodgepole pine slash
	S-2	White spruce-balsam fir slash
Other	O-1a	Matted grass
	O-1b	Standing grass

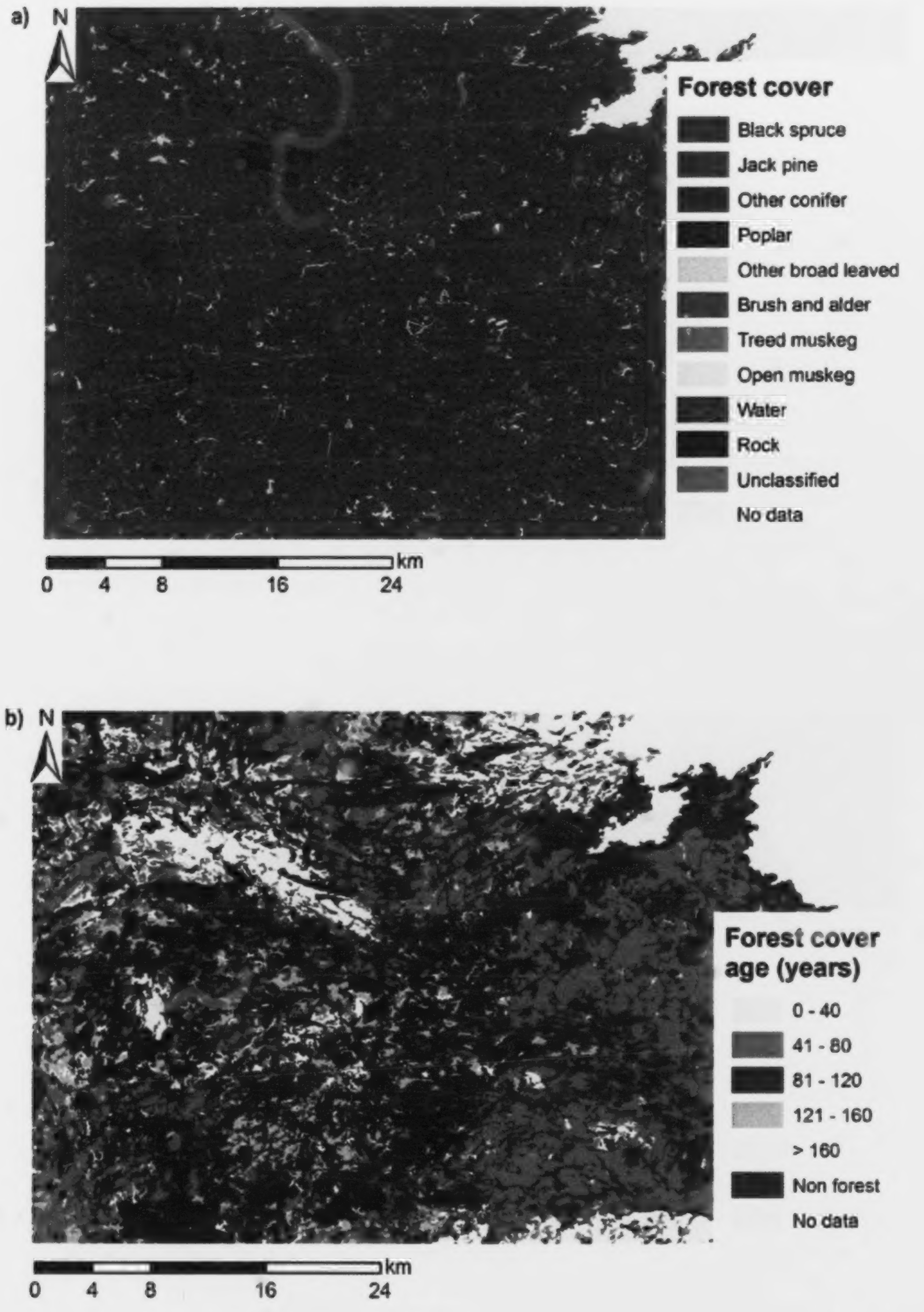


Figure 2. *Forest cover (a) and its age (b) in the area of the RED-084 fire. The polygon in Figure (b) indicates the location of the 1999 fire RED-058.*

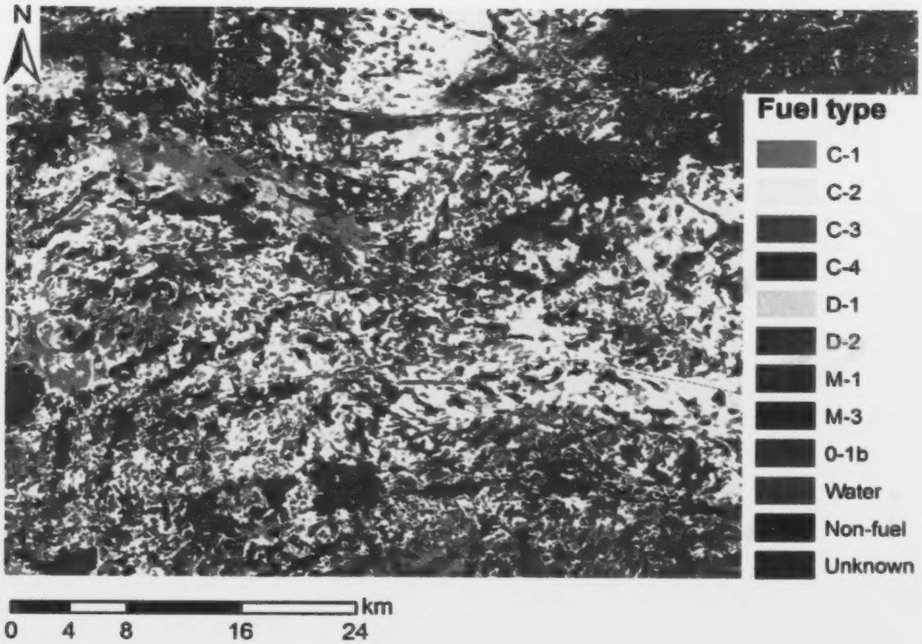


Figure 3. *Forest fuel types in the area of the RED-084 fire. See Table 2 for details of fuel types.*

Before the fire occurred, wind and weather events had caused large areas of wind throw in the area (Figure 4). These areas of dead trees can contribute significantly to local fire intensity and represent a change in fuel type. The area of RED-084 was dominated by mature forest that was scheduled for timber harvesting. A new road had been built into the area, and the harvesting operations had begun just before the fire. As a result, cut wood was stacked alongside the road under construction and spread out over two cut blocks in piles created during the harvest.

To better reflect fuel at the time of fire, fuel types in the area of the RED-084 burn were modified to account for the previous disturbances including the 1999 RED-058 burn (C-4: immature jack pine), and a large area of windthrown trees, referred to as blowdown, and recent harvesting activity (S-1: jack pine slash). The revised fuel map is provided in Figure 5.

Figure 4. Example of pre-burn blowdown in the area of RED-084 fire.

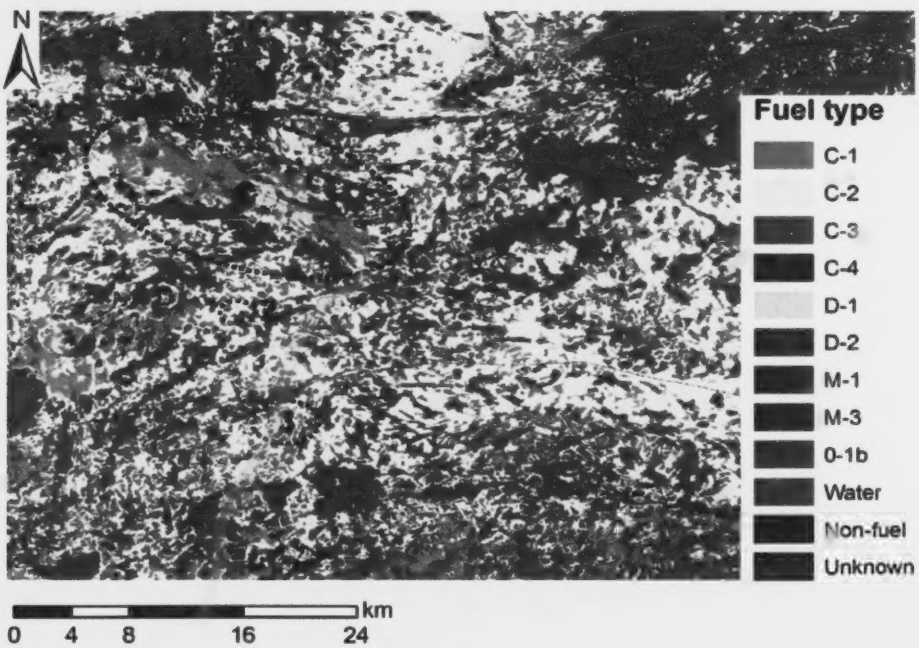


Figure 5. Forest fuel types in the area of RED-084 fire were modified to account for old burn (polygon 1), harvest (polygon 2), and blowdown (polygon 3). See Table 2 for details of fuel types.

3.0 Fire Event

RED-084 was one of Ontario's largest fires in 2011 (AFEES website). In the following section, we describe the fire's initiation, progression, extinguishment, and final characteristics.

3.1 Ignition

RED-084 was reported as a lightning-caused fire on the afternoon of July 10, 2011 at 16:00. At the time of detection it was estimated at 3.0 ha. The fire is considered to have ignited northeast of Ear Falls, Ontario (Figure 6) in mature forest.

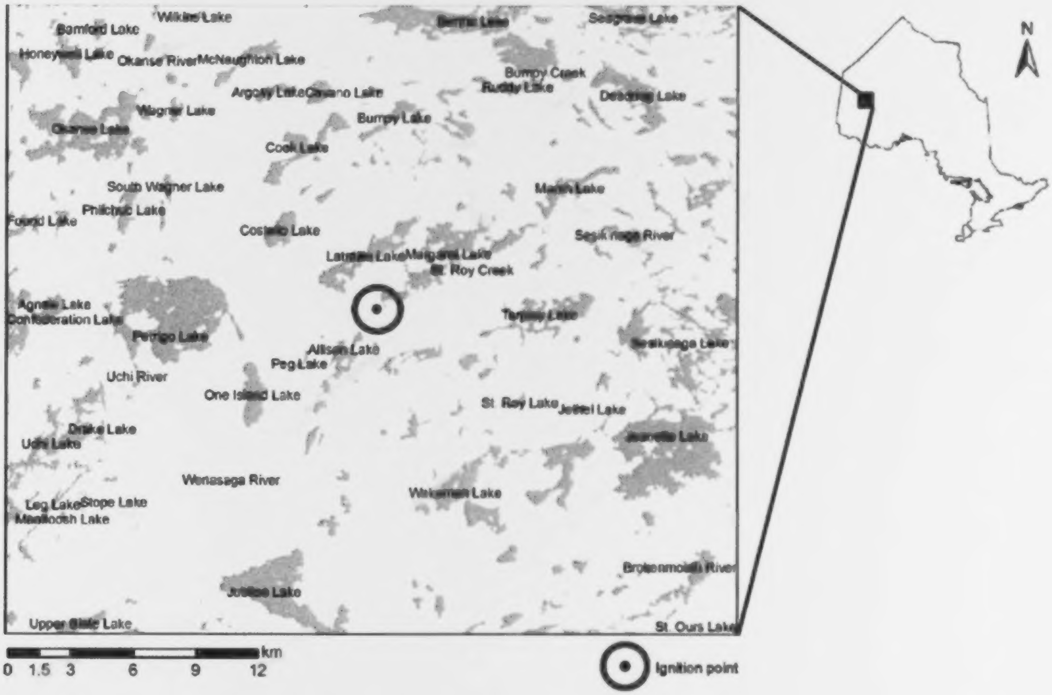


__Figure 6.__ Approximate location of the ignition point of RED-084 in northwestern Ontario.

3.1.1 Fire weather at time of ignition

Temperature, relative humidity, rain, and wind information from the weather station closest to fire's origin, known as the South Bay station, was used with the Canadian Forest Fire Weather Index (FWI) System (Van Wagner and Pickett 1985) to derive fire weather conditions at the estimated time of ignition. These weather and FWI parameters, which describe condition of fuel and expected fire spread, are provided in Table 3.

Table 3. Weather and fire weather indices at estimated time of ignition based on weather data obtained from the closest weather station (South Bay). See Figure 7 for the location.

Fire weather parameter	Value
Relative humidity (RH) (%)	26
Temperature (°C)	27.5
Wind speed (WS) (km/hr)	18.1
Rain (mm)	2.8*
Fine fuel moisture code (FFMC)	87.5
Duff moisture code (DMC	71
Drought code (DC)	227
Initial spread index (ISI)	7.4
Build-up index (BUI)	80
Fire weather index (FWI)	23

*Observations by fire crews indicated that it did not rain in the area where the fire started.

3.1.2 Fire weather conditions prior to ignition

The weather station closest to the fire and that was used by MNR crews to report fire weather during the fire fighting operation was the South Bay weather station, located approximately 25 km from the fire ignition point (Figure 7). Weather and fire weather indices from the station in the 30 days leading up to fire ignition are shown in Figure 8. Very little rain had fallen in the month prior to the fire event, as a result the drought code and build up indices had increased steadily.

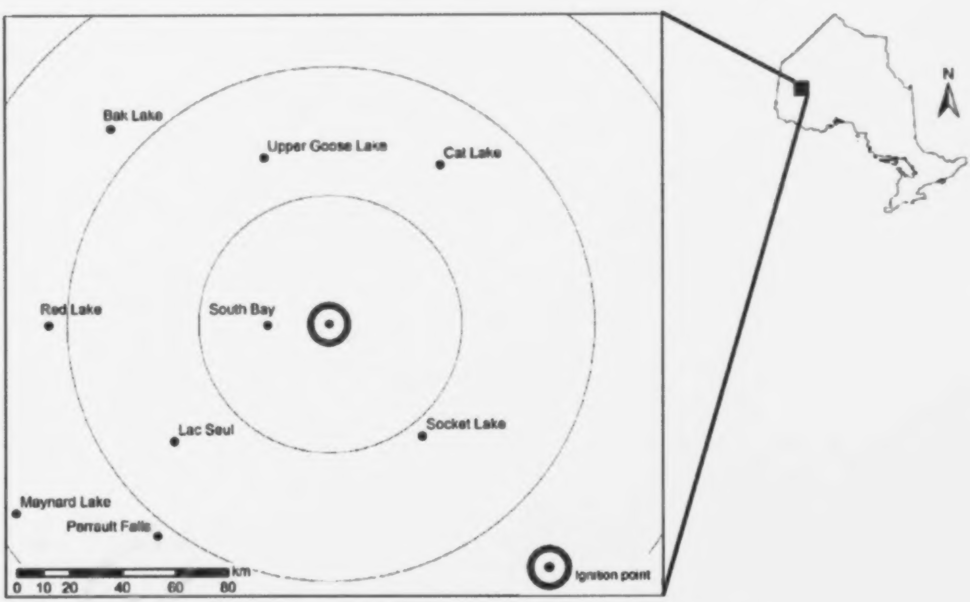
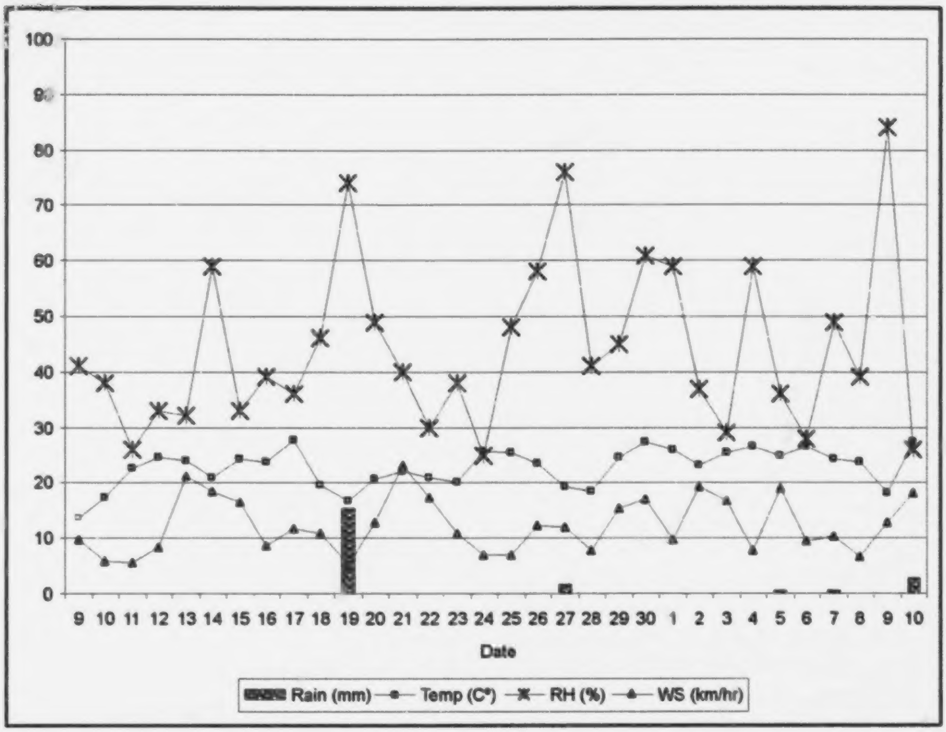


Figure 7. Weather stations within 50 km, 100 km, and 150 km of RED-084's ignition point.

a)



b)

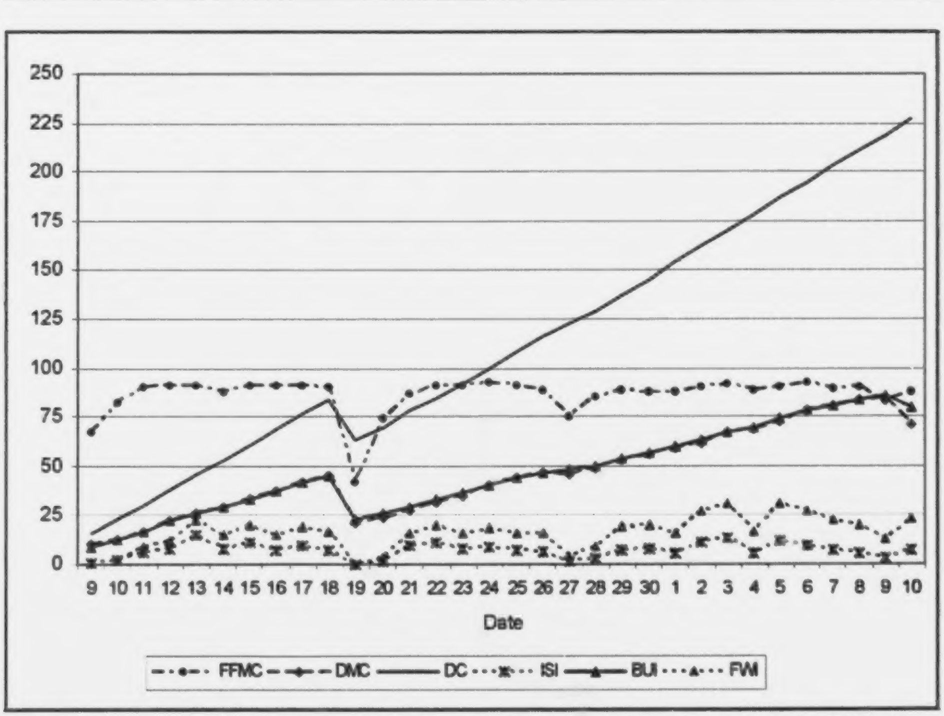


Figure 8. *Weather pattern for the 30-day period (June 09-July 10, 2011) prior to ignition of RED-084 (a) and associated fire weather indices for that period (b) as observed at South Bay weather station. For details of the indice acronyms see Table 3.*

3.2 Fire progression

RED-084 burned for 23 days in midsummer. As it burned, its progression had been mapped at periodic intervals. The progression of how the fire advanced and the area burned over time is illustrated in Figure 9 (note that the time intervals are irregular). The general direction of fire spread was northeast.

The initial boundary of RED-084 had been hand drawn on an aerial photo and transferred to digital format at MNR's fire management headquarters. Once the incident management team had arrived at the fire, on July 13, all further areas were mapped using hand held GPS from an aircraft as per MNR's fire mapping protocols (OMNR 2011). The mapping flights were done in the early mornings, before smoke and other air traffic in the area made low level flying around the fire perimeter dangerous. Aerial mapping flights were supplemented later by GPS information provided by ground crews, resulting in adjustments to both the progression steps and the final fire perimeter.

3.2.1 Rate of spread

The progression of RED-084 was typical of most large fires with a series of growth spurts influenced by weather conditions and fire suppression activities. Initially the estimated rate of spread (ROS) was 8 to 10 m min^{-1} (Table 4) with the fire advancing 14 km despite the efforts of suppression aircraft (for details see fire suppression section below) to slow the progress. From July 11 to 13, the wind direction changed and the fire advanced only about 1 km but increased some 1200 ha. Over the next two days, the fire nearly doubled in size to 11,187 ha. It then slowed significantly for two days, likely due to the 6.0 mm of precipitation recorded on site. As the effect of that moisture dissipated, the fire advanced another 3 to 5 km, growing from 14,238 to 21,456 hectares by early July 19.

The fastest rate of spread was recorded July 19-20, with the fire advancing almost 16 km in 24 hours. Without adjusting for the nocturnal decrease in fire activity, this equates to a sustained ROS of 8.3 m min^{-1} over a 32-hour period. After adjustment, to consider the diurnal fire spread by reducing the active fire period to an 18-hour time frame, ROS estimates increase to 14.8 m min^{-1}. Rainfall on July 20 and 21 significantly reduced fire activity for 7 to 10 days with the next major expansion of about 8 km recorded July 30-31. This was followed a day later with close to a 4 km expansion resulting in the approximate final size of the burned area of 42,765 ha (area of water excluded).

Rates of spread at peak burn times, estimated using the Canadian Forest Fire Behaviour Prediction (FBP) System for the C-2 fuel type, are much higher than average rates of spread (Table 4). These values of ROS indicate that RED-084 ranged from a very slowly spreading intermittent fire to a high intensity crown fire.

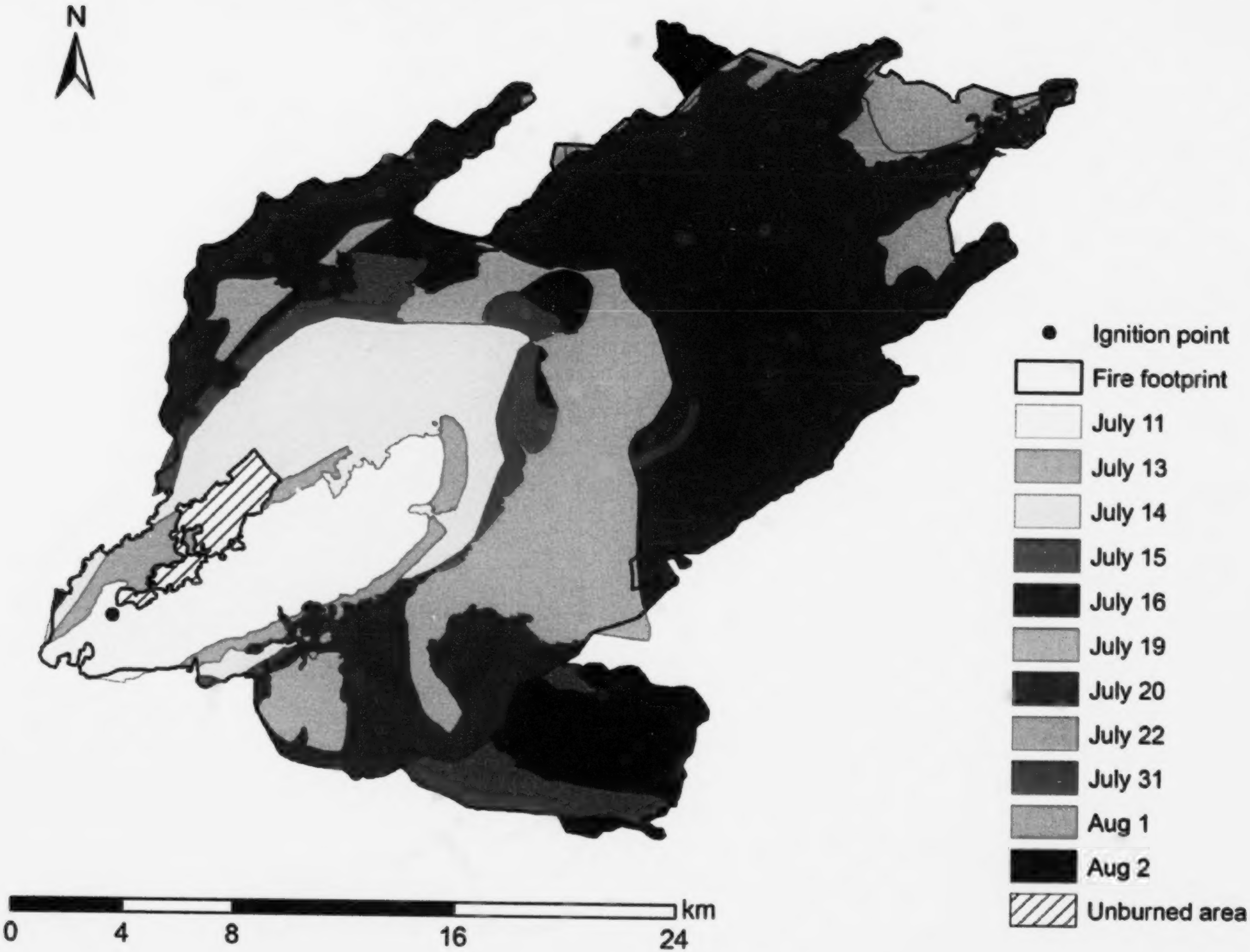


***Figure 9**. Progression of RED-084 fire from ignition point on July 10 to last day of fire spread on Aug 02 (note that the time intervals are not equal).*

Table 4. Average rates of spread (ROS) for the major progression steps documented for RED-084 (data from field fire crew reports, OMNR AFFES 2011, unpubl.).

Progression step interval	Distance of head fire progression (km)	Area burned during interval (ha) [1]	Averaged ROS (m min^{-1})	ROS (m min^{-1}) in C-2 fuel at peak burn based on FBP [2]
July 10 16:30 -July 11 21:00	14.2	4762	8.3	23 (July 10)
July 11 21:00 - July 13 16;30	1.0	1281	0.4	6 -7 (July 12)
July 13 16:30 -July 14 19:00	4.0	5144	2.5	11 (July 13)
July 13 19:00 -July 16 21:00	4.1	3051	1.0	23 (July 14)
July 16 21:00 -July 19 10:00	≈5.0	7218	1.4	21 (July 18)
July 19 10:00 -July 20 18:00	16.0	18401	8.3	24 (July 19)
July 20 18:00 - July 22 14:00	1.0	≈100	0.8	3 (July 21)
July 22 14:00 -July 31 14:00	8.0	22	0.6	12 (July 31)
July 31 14:00 -Aug 2 14:00	4.0	2886	1.4	13 (Aug 1)

[1] Area of water excluded from these area estimates

[2] Taylor et al. 1997

3.2.2 Fire weather during the fire

Fire spread is very much influenced by weather conditions. During the period that RED-084 burned, very little rain fell and the drought code, which is an estimate of the moisture content of the deep organic layers, increased steadily indicating that forest fuels were getting drier. Weather conditions observed at South Bay weather station during the fire are summarized in Figure 10.

a)

b)

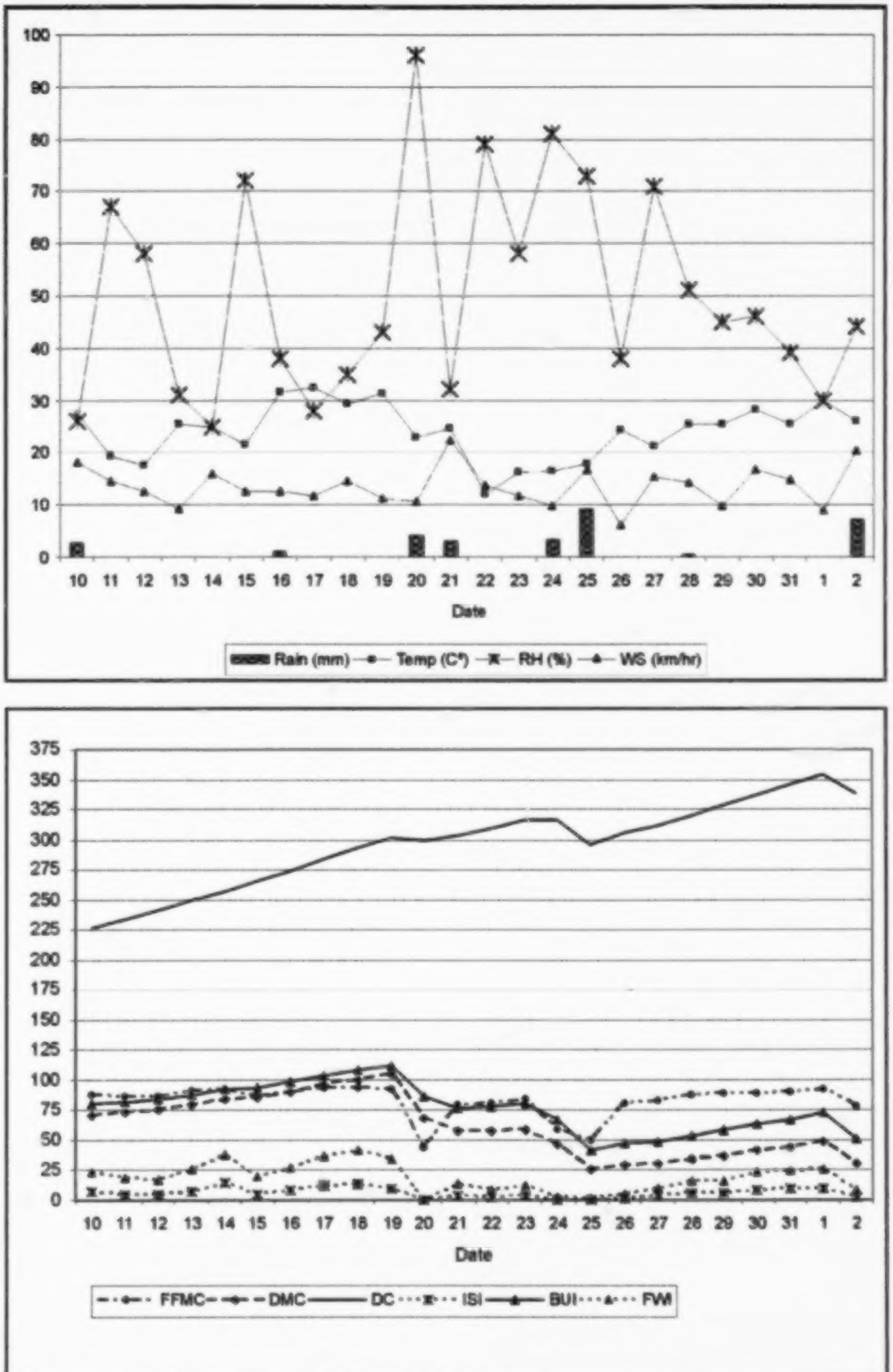


Figure 10. *Weather pattern for the 23-day period (July 10-August 02, 2011) of fire spread in RED-084 (a) and associated fire weather indices for that period (b) as observed at South Bay weather station. For details of the indice acronyms see Table 3.*

3.3 Fire suppression

In Ontario, forest fires are suppressed to protect public safety and property (OMNR 2004). In the area of RED-084, infrastructure considered a priority for protection included the power transmission line that traversed the area and several, mostly commercial, outpost camps and docks (Figures 11-13).

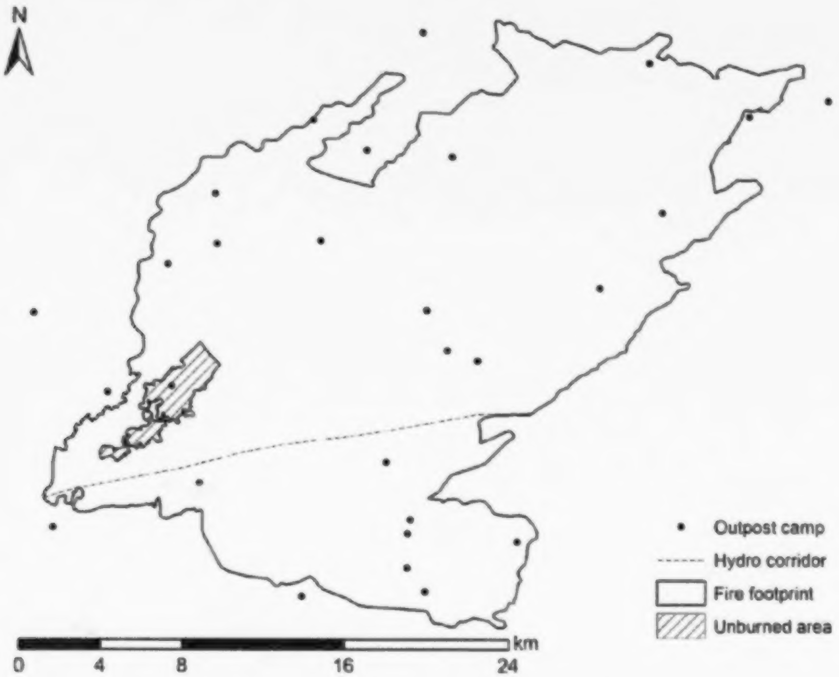


Figure 11. Infrastructure in the proximity of RED-084 identified as high priority targets for fire protection efforts.

Figure 12. Protecting the hydro line that traversed the area was a high priority for fire suppression crews but the fire burned across the line requiring restoration efforts.

Figure 13. Commercial outpost camps used for fly-in fishing and hunting were high priority targets for fire suppression efforts.

Fire suppression activities began on July 10, the day the fire was reported, and ended on September 3 when the fire was declared under control. During that period, a total of 2964 water bomber drops (water and foam plane loads) occurred. The primary goal of water bomber attacks was to protect the infrastructure, including the power transmission line and the outpost camps, in the area and to slow the growth of the fire. The locations of suppression efforts during the period of the fire are shown in Figure 14. Figures 15 and 16 show examples of the suppression efforts conducted with water bombers and helicopters.

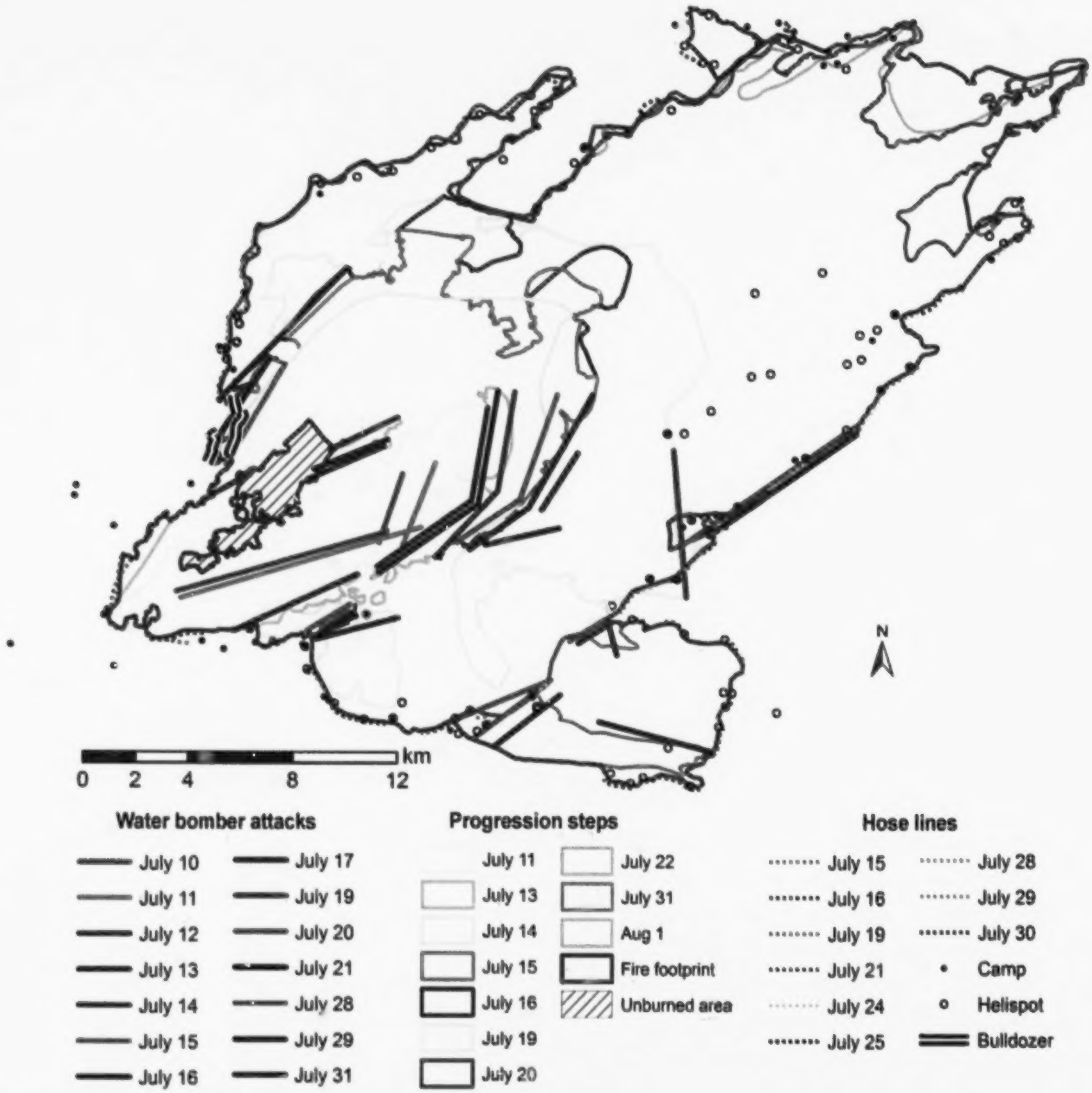


***Figure 14**. Map of fire area of RED-084 with locations of fire suppression activities.*

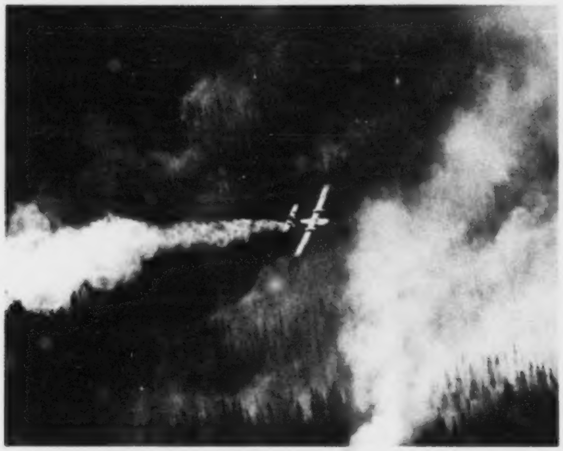


Figure 15. Water bomber attack on the RED-084 during suppression efforts.

Figure 16. Water drop from helicopter bucket in RED-084.

In addition to water bomber drops, ground crews used bulldozers and fire hoses to stop the fire from spreading. Bulldozers were used on the west side of the fire to create fire breaks (Figure 17). Over 100 km of fire hose line were used over the duration of the fire, for example, to install sprinklers to protect infrastructure (Figure 18). In addition, over 833 helicopter trips were logged to provide services such as inspecting fire progression, transporting crews and equipment, as well as occasional dropping of water (the latter are not included in Figure 16.) The details of suppression costs incurred in RED-084 were not available at time of writing.

Figure 17. Bulldozers were used on the west side of the fire to create fuel breaks.

Figure 18. Hose lines and sprinklers were installed to protect outpost camps in the area of the fire.

3.4 Extinguishment

RED-084 stopped spreading on August 2, at which time the total length of fire perimeter was 168.5 km. To provide an indication of what stopped the fire, we determined the forest cover types associated with the perimeter for each progression step of the fire as a percent of the length of perimeter for that step (Table 5). Cover types thought to act as fuel breaks include water, rock, and muskeg. Very little of the RED-084 perimeter was rock (<1%) or muskeg (<2%), but water represented 35% of the length of the final perimeter. Depending on progression date, water represented between 8.1 (July 19) and 91.5 (July 13) of the edge of the fire and represented the majority of the perimeter at the beginning of the fire (July 11-14) and again on July 31. Except for July 11, the black spruce cover type represented a higher percentage of the perimeter than the jack pine cover type.

3.5 Fire footprint characteristics

The final perimeter for the fire was mapped (details of mapping methods were not available at time of writing) on Aug 2, 2011, when the fire was deemed as having stopped spreading (Figure 19). The fire burned a total of just under 55,000 ha in 23 days, despite continuous suppression efforts. Here we provide a summary of the forest cover, age, and fuel types burned by the fire, based on the final fire perimeter, as mapped by AFFES (OMNR 2011).

***Table 5**. Percent of length of fire perimeter by FRI forest cover type class for mapped fire progression steps.*

Cover type	Percent of length of perimeter by fire progression date											Final
	July									August		
	11	13	14	15	16	19	20	22	31	01	02	
Black spruce	16.6	7.6	6.6	60.3	48.3	82.1	54.5	44.5	25.2	50.9	39.4	45.2
Jack pine	22.3	0.0	6.3	16.6	11.7	0.0	12.0	12.8	0.0	1.0	10.9	9.7
Other conifer	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2	1.0	0.2
Poplar	0.0	0.9	0.9	0.9	12.3	0.0	3.0	7.9	1.3	0.0	0.0	2.1
Other broad leaved	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0
Brush and alder	0.0	0.0	0.1	0.0	0.0	0.0	0.3	0.0	0.0	0.5	0.8	0.3
Treed muskeg	1.1	0.0	0.0	0.0	12.5	9.7	1.7	0.4	0.0	0.6	0.4	1.4
Open muskeg	0.0	0.0	0.0	0.5	0.0	0.0	0.5	2.3	0.0	0.3	2.3	0.7
Water	59.2	91.5	86.1	21.6	15.0	8.1	24.4	23.9	72.3	35.1	44.1	36.7
Rock	0.3	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.3

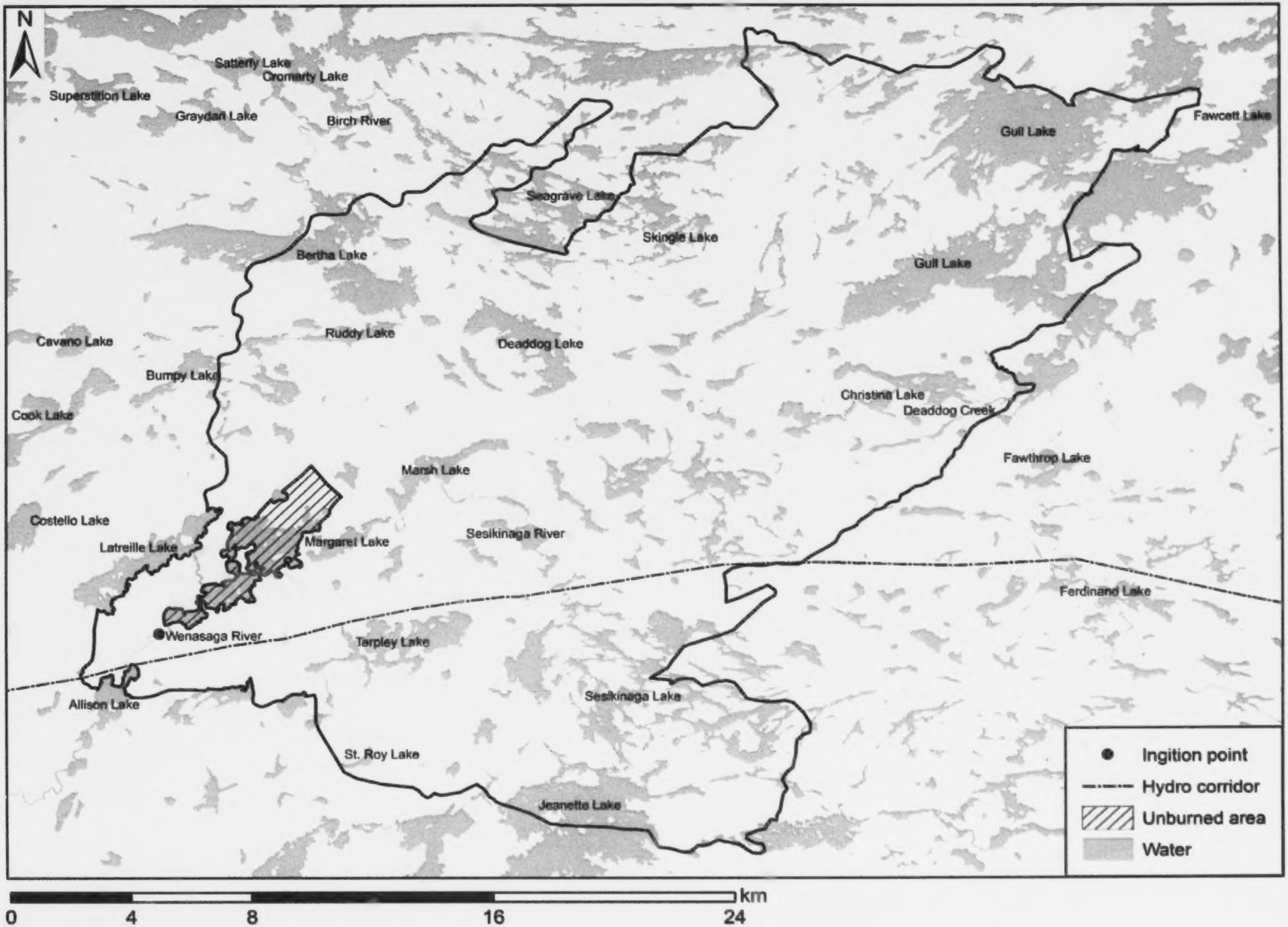


Figure 19. *Final RED-084 fire footprint with the ignition location and perimeter, as mapped by MNR fire crews.*

3.5.1 Cover type composition

Figure 20 shows the composition of pre-burn cover types within the final footprint of RED-084, by pre-burn cover types and Figure 21 shows the progression steps of the fire by pre-burn cover types.

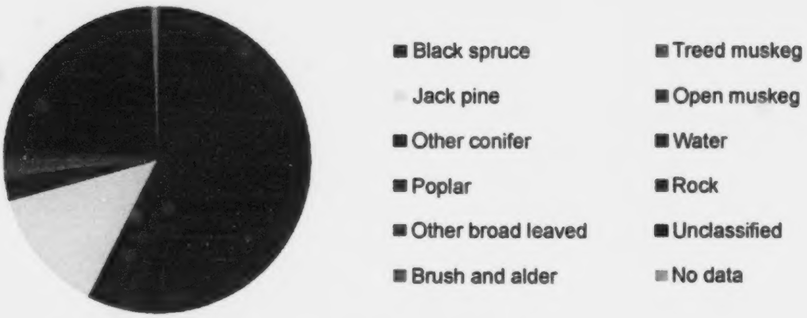


Figure 20. Pre-burn cover type composition within the final footprint of RED-084.

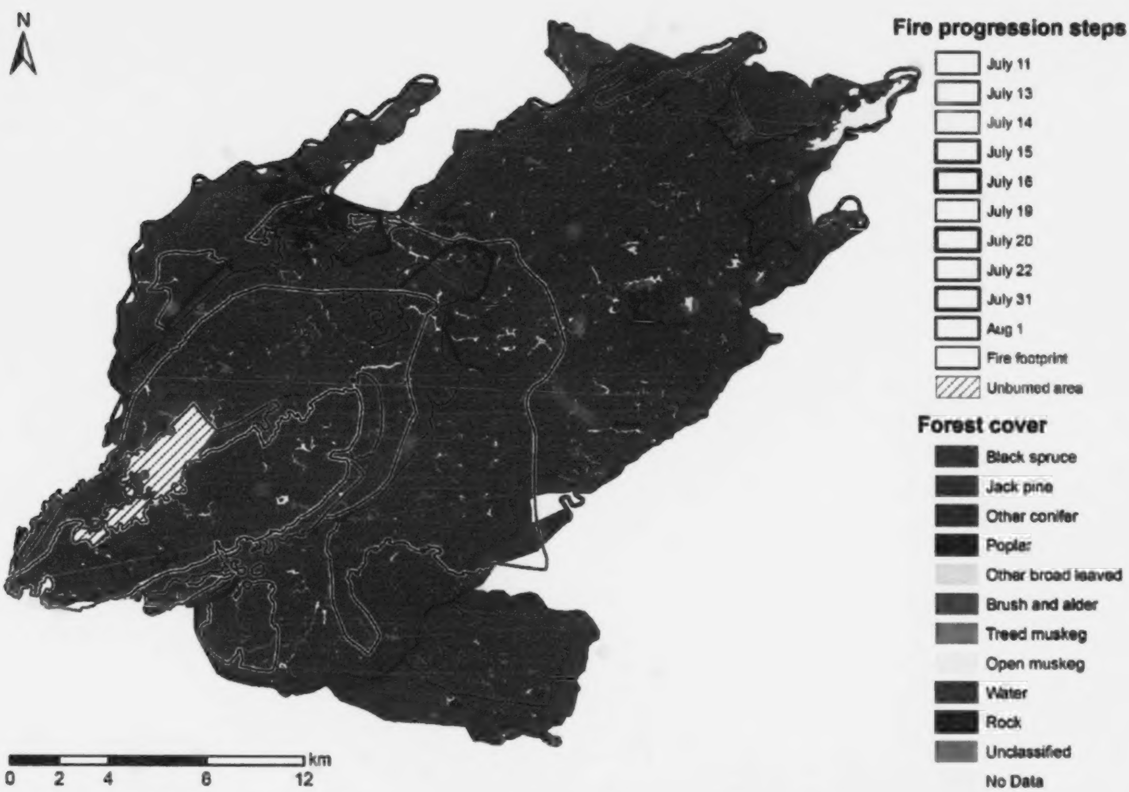


Figure 21. RED-084 fire footprint and steps of fire progression with pre-burn spatial distribution of cover types.

3.5.2 Forest age composition

Figure 22 shows the composition of pre-burn forest age classes within the final footprint of RED-084, by pre-burn forest age classes and Figure 23 shows the progression steps of the fire by pre-burn forest age classes.

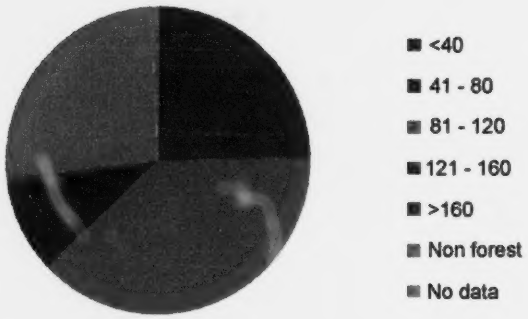


Figure 22. Pre-burn forest age class composition within the final footprint of RED-084.

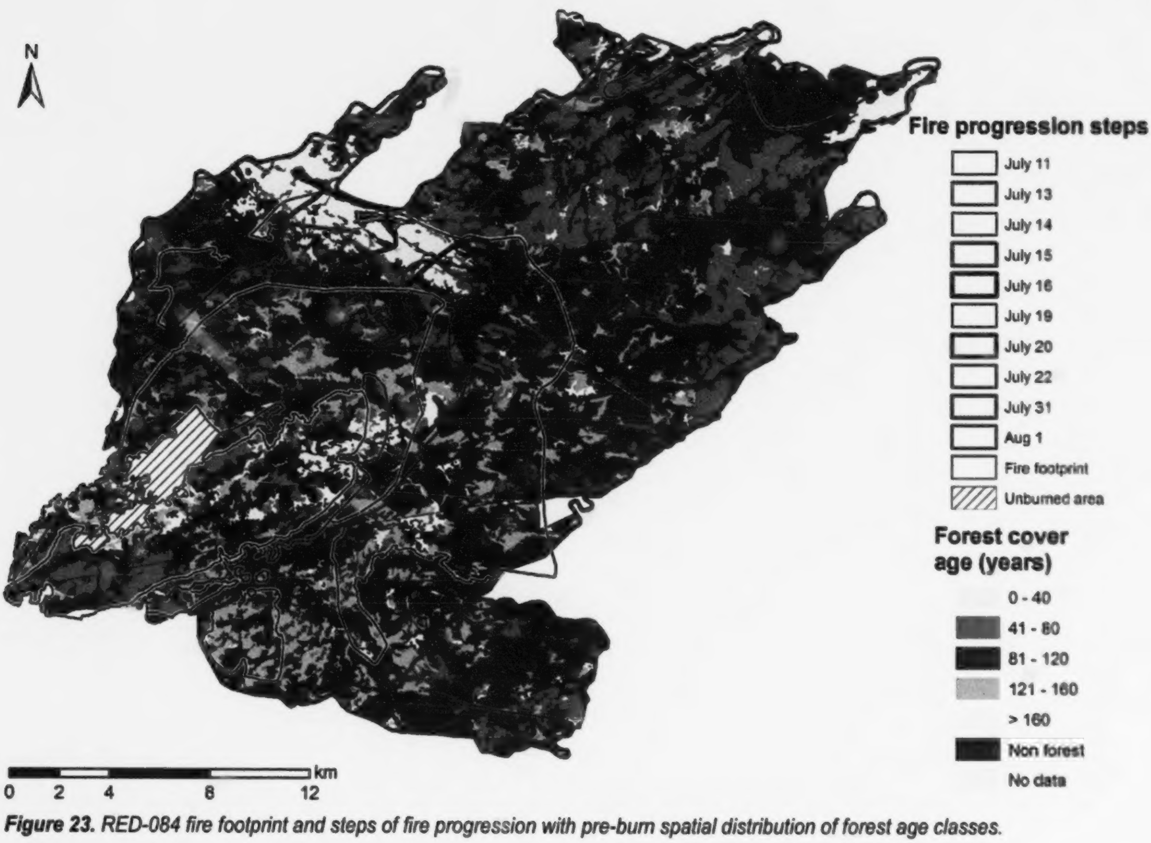


Figure 23. RED-084 fire footprint and steps of fire progression with pre-burn spatial distribution of forest age classes.

3.5.3 Fuel type composition

Figure 24 shows the composition of pre-burn fuel types within the final footprint of RED-084, by pre-burn fuel types and Figure 25 shows the progression steps of the fire by pre-burn fuel types.

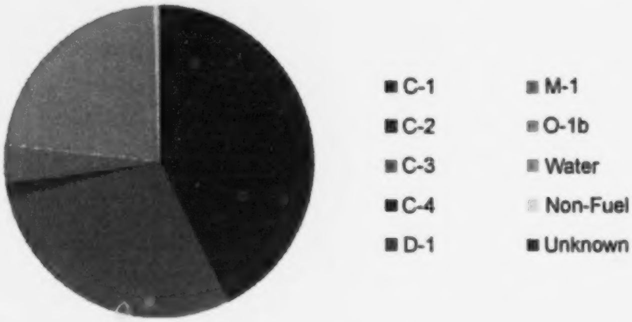


Figure 24. Pre-burn fuel type composition within the final footprint of RED-084. For details about fuel types, see Table 2.

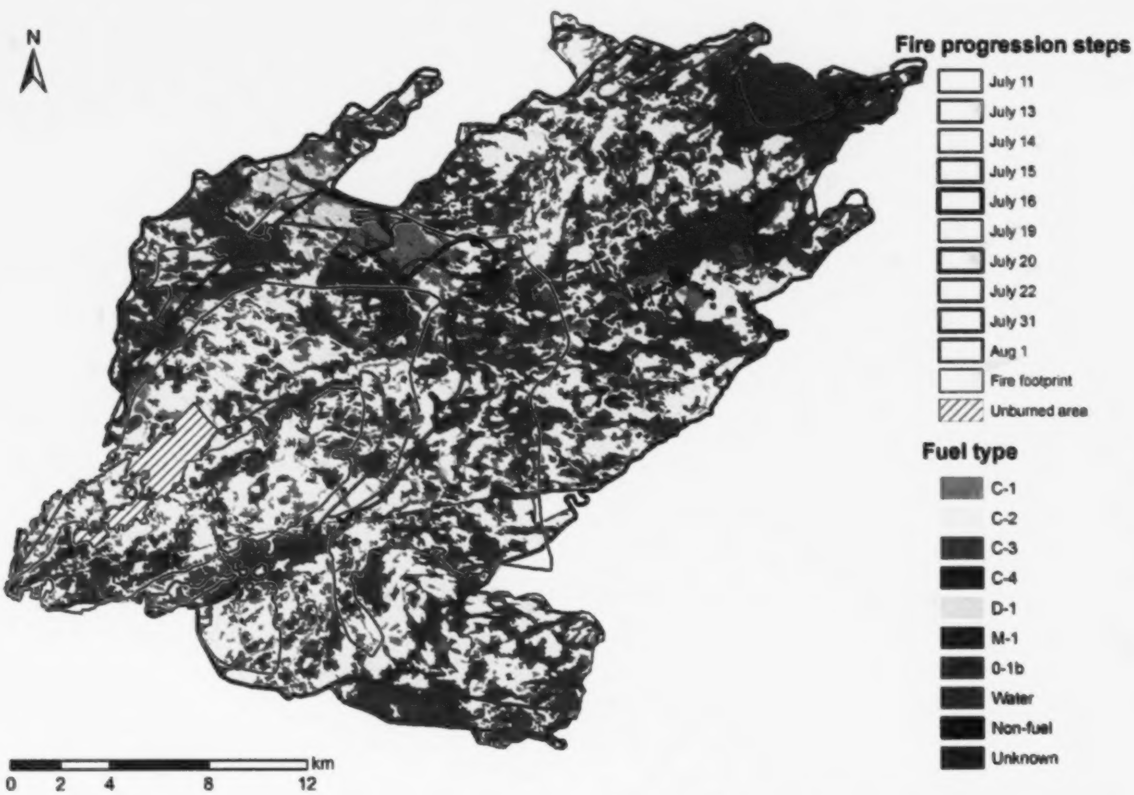


Figure 25. RED-084 fire footprint and steps of fire progression with pre-burn spatial distribution of fuel types. For details about fuel types, see Table 2.

4.0 Post-fire Survey

4.1 Fire patterns and scale

Spatial patterns that result from forest fire, like most ecological features, are not scale-independent, and would differ based on the spatial scale and resolution of observation. Description and quantification of post-fire characteristics must therefore specify the scale of observation and measurement. Scale also affects the accuracy and precision of information gathered, and the inferences thus formulated. In the following sections, we describe post-fire patterns in RED-084 based on two distinct scales of observations: an air survey and a ground survey.

4.2 Air Survey

The air survey was conducted by fixed-wing aircraft, at a general altitude of 600 m on October 04, 2011 (31 days after the fire was declared under control). The total flight time over the fire was 2 hours, following a pre-determined traverse pattern that was based on the final fire perimeter map (Figure 26). The visual observations and recording of still images were guided by GPS. Here we describe our observations of RED-084 in relation to the fire footprint, spot fires, unburned residual patches, blowdown, and forest harvest. Further details of photographic evidence are provided in Appendix A.

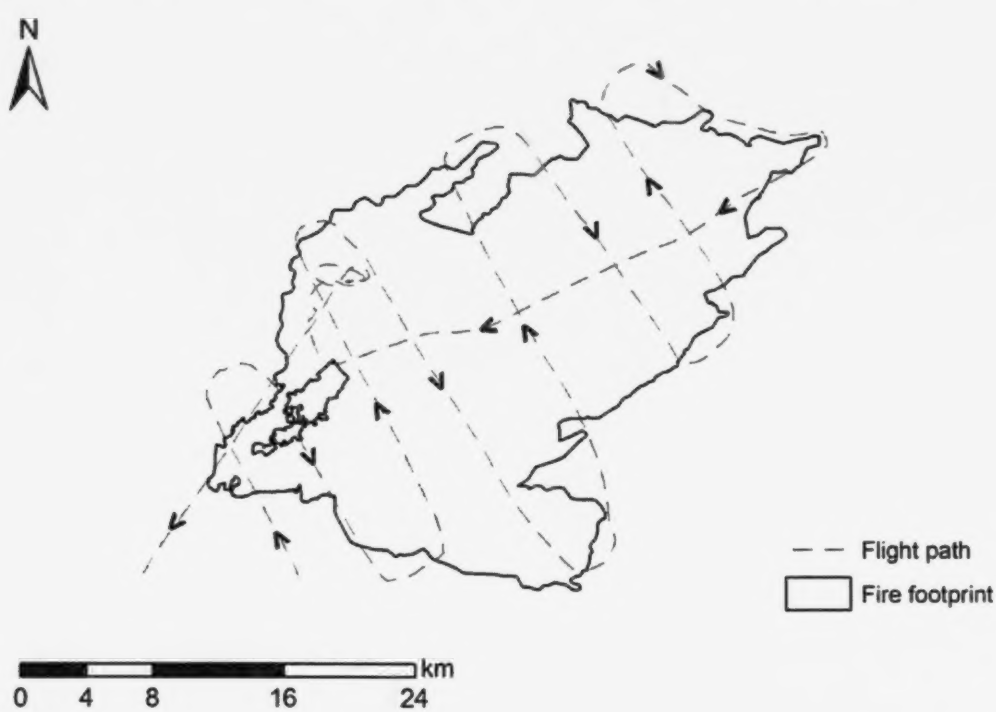


Figure 26. The path of the aerial reconnaissance survey of RED-084.

4.2.1 Fire footprint

The fire perimeter as mapped by MNR's AFFES (2011 unpubl.) appeared to be accurate from our observations; based on the geographic coordinates (latitude - longitude) acquired during the flight compared with the GIS data of the mapped fire perimeter. However, in several instances burnt forest area was evident beyond the mapped fire perimeter (Figure 27).

Figure 27. *Some burned areas occurred outside the mapped fire perimeter (this example from southwestern edge of the fire, near Allison Lake).*

Another obvious feature was the lack of a discrete transition at the edge of the fire, from burned area within to unburned area outside. Most times, the fire perimeter consisted of forest cover with a gradient of burn severity – from completely charred to completely unburned forest cover with mixture of burned and unburned cover in between (Figures 28 and 29).

Figure 28. *The fire perimeter often is not a sharp transition from burned to unburned, even at the edges of lakes (this example from the northwestern edge of the fire, near Bertha Lake).*

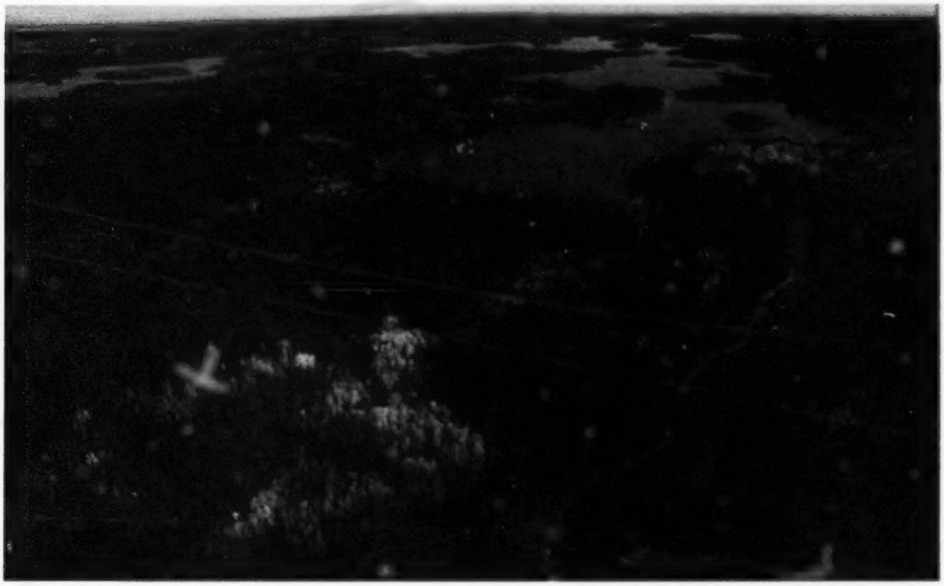


Figure 29. Gradual transition from burned to unburned is evident even within the fire (this example from near Wenasaga River and Margaret Lake).

A considerable extent of water bodies (Figure 30) and unburned forest area (Figure 31) occur within the fire footprint. Existence of non-burned area within the fire perimeter will vastly exaggerate the estimates of the area burned if those are derived directly as area within the mapped fire perimeter.

Figure 30. Many water bodies occur within the fire perimeter (this example overlooks Sesikinaga Lake in the southern part of the fire).

Figure 31. Large extent of unburned area exists within the fire perimeter (this example is from the western part of the fire).

Overall, a great degree of spatial heterogeneity in burn severity was apparent throughout the fire footprint (Figures 32, 33, and 34). This is rather surprising given the intensity and size of the fire and the rapid rate at which it progressed over large areas.

Figure 32. Spatial patterns within the fire are highly heterogeneous with respect to burn severity; this example is a low severity burn area in the centre of the footprint, where fire progressed most rapidly.

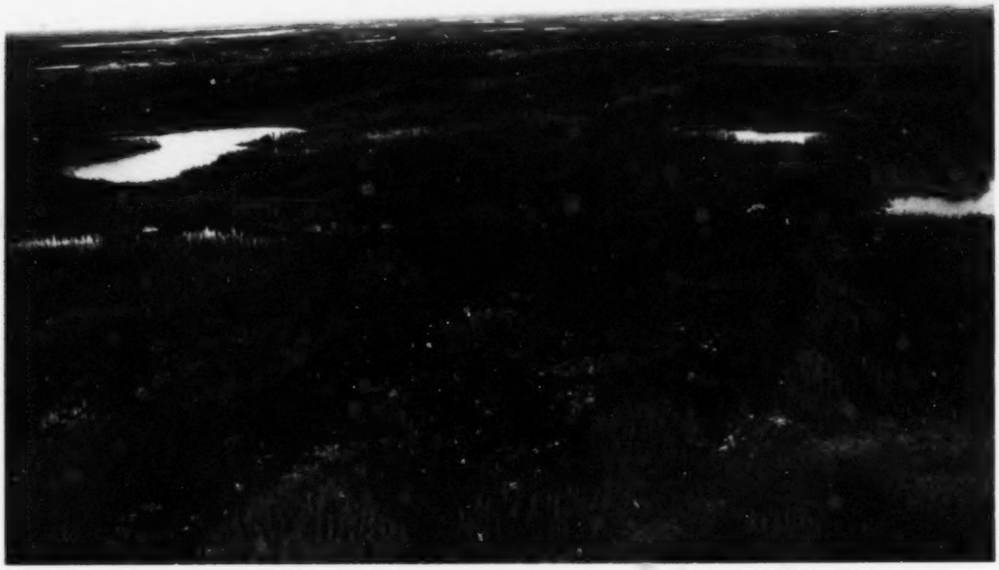


Figure 33. *High severity burnt area near the southeastern edge of the fire.*

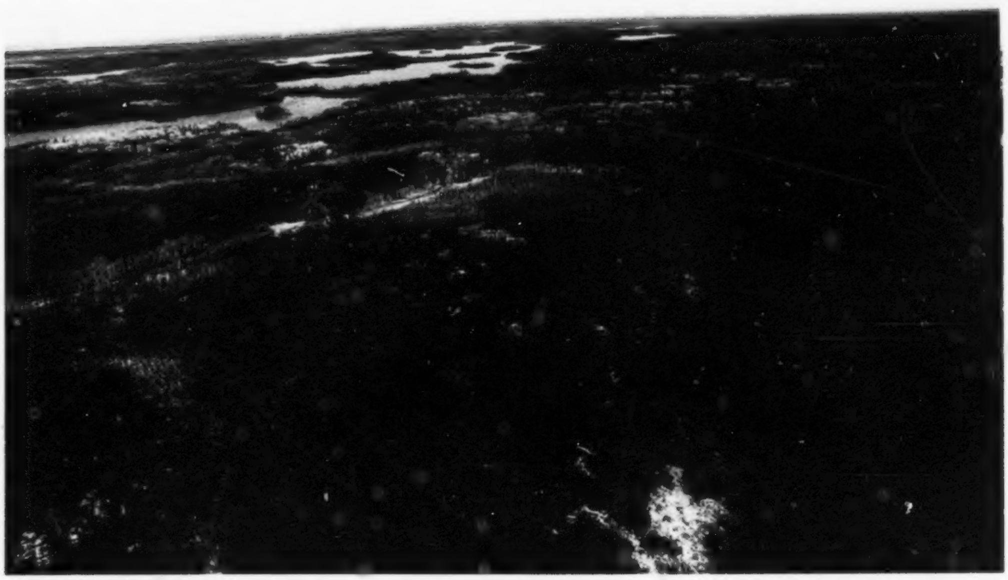


Figure 34. *High severity burnt area in the southern edge of the fire (this example is near Allison Lake).*

4.2.2 Spot fires

Spot fires occur in intense wildfires when convection columns transport embers of varying sizes to long distances and start ignitions beyond the normal fire spread, typically in front of the head fire. For example, field reports of RED-084 had indicated three spot fires in front of the head fire and flanks on July 13. Results of such spotting were distinct from the air as isolated burned areas outside the perimeter, in all flanks, but were especially abundant in the north-northeastern part of the fire footprint. This may be because the main axis of the fire spread was from SW to NE, and spotting may have been common towards the flanks of the head fire (Figure 35). Some spot fires had occurred within the fire perimeter as well (Figure 36). In addition, internal fire spotting had burned many islands within large lakes inside the fire footprint, some of which appeared to be several hundreds of metres from the shore (Figure 36).

Figure 35. Spot fires are common around the flanks of the head fire (this example is at the northern edge of the fire, near Seagrave Lake).

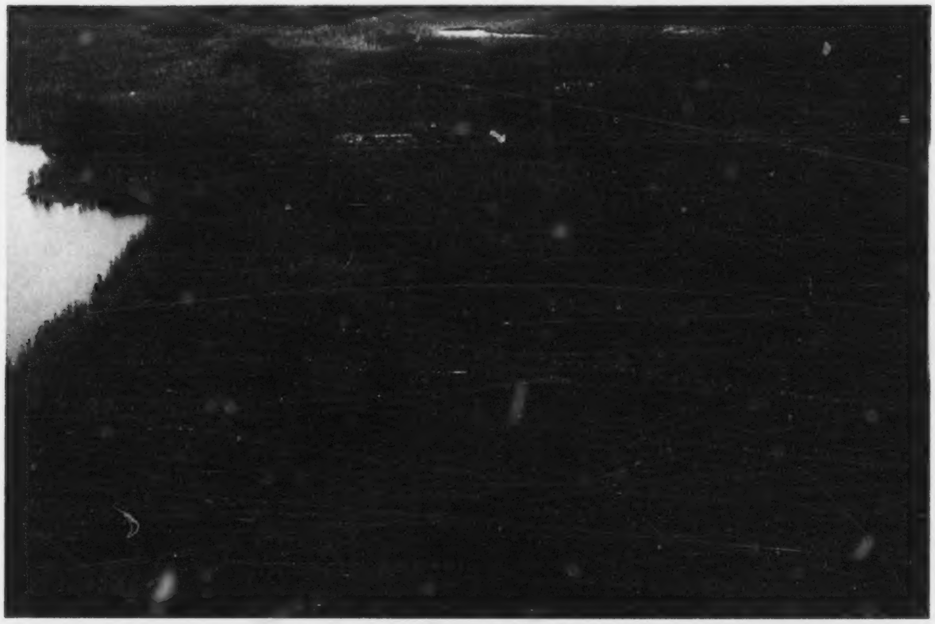


***Figure 36**. Spot fires occurred within the fire perimeter as well, as seen in this example from the western part of the fire.*

***Figure 37**. A spot fire that burned an island in Gull Lake at the northeastern edge of the fire inside the perimeter.*

4.2.3 Residual patches

Owing to the three-way interaction among the fire intensity, physiography, and spatial arrangement of cover types, wildfires leave islands of unburned areas referred to as residual patches. RED-084 was no exception as we witnessed a large number of residual patches within its perimeter. These occurred in an array of sizes and shapes, and were located throughout the fire footprint, with no consistent spatial pattern of occurrence or bias towards cover types or physiographic features (Figures 38 and 39).

***Figure 38.** Residual patches of different cover types occur throughout the fire (this example from the southern part of the fire).*

***Figure 39.** Residual patches exist in a variety of physiographic settings within the fire (this example near Bumpy Lake in the western part of the fire).*

4.2.4 Blowdown

Large areas of blowdown were visible within the fire footprint. The felled trees were burned in most cases (Figures 40 and 41), but some clusters of unburned trees lying on the ground were also seen inside the fire perimeter (Figure 42) suggesting that these tracts of wind throw must have occurred before the fire.

Figure 40. *Most blowdown area within the fire had burned (this example is from the northwestern part of the fire, near Ruddy Lake).*

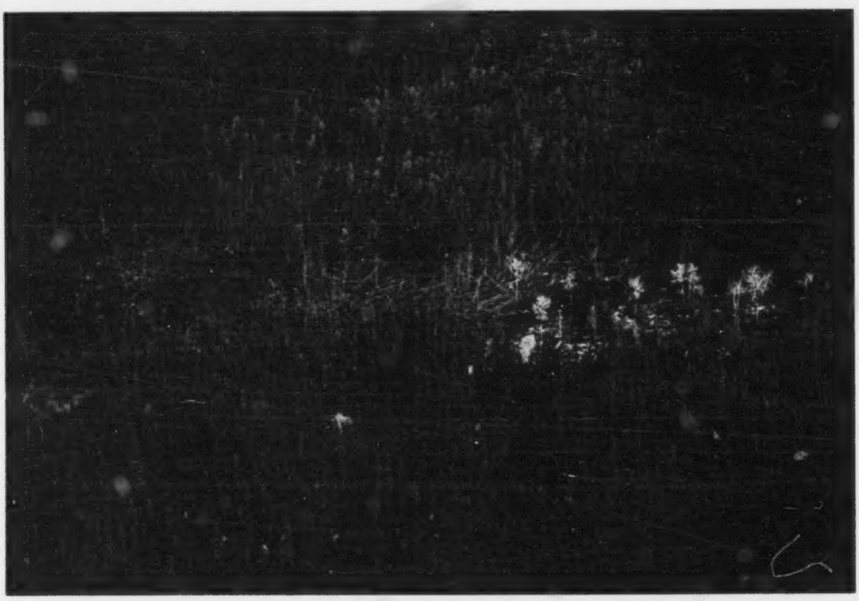


Figure 41. *Blowdown area that had burned near Tarpley Lake in the southern part of the fire.*

Figure 42. Some blowdcwn area had escaped severe fire, as seen in this example near Tarpley Lake.

4.2.5 Harvest

As mentioned earlier, a portion of the forest cover in the northwestern corner of the fire footprint had been harvested just before the fire. From the aerial survey, it seemed as if the fire had progressed across the harvested areas unabated. The fire had burned through the harvested area (Figure 43 and 44) as well as the stacks of the harvested timber.

Figure 43. The recently harvested area in the western part of the fire had burned, including unharvested patches.

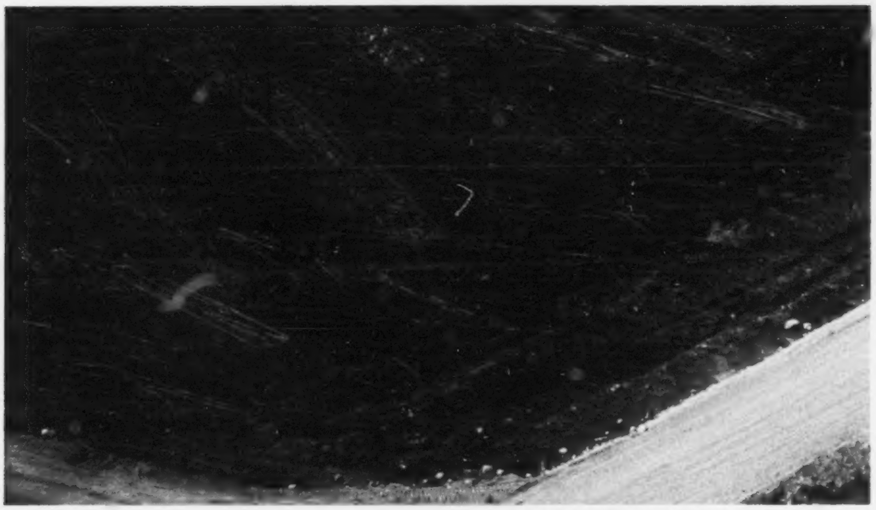


***Figure 44.** Many stacks of harvested timber were burned during the fire.*

4.3 Ground Survey

The road from Ear Falls continues as a logging road, which had been constructed during winter 2010 to spring 2011, which provided convenient access to the western part of the fire (Figure 45). This road extends 9.8 km into the fire, almost approaching Dead Dog Lake. On October 05 and 06, 2011 we made several excursions into the fire from several points along the road, totalling 16.8 km (Figure 46). We describe below our observations at the ground level in relation to pre-burn conditions, fire behaviour, residuals, blowdown, harvest, animal activities, and regeneration within the fire footprint. Further photographic evidence is provided in Appendix B.

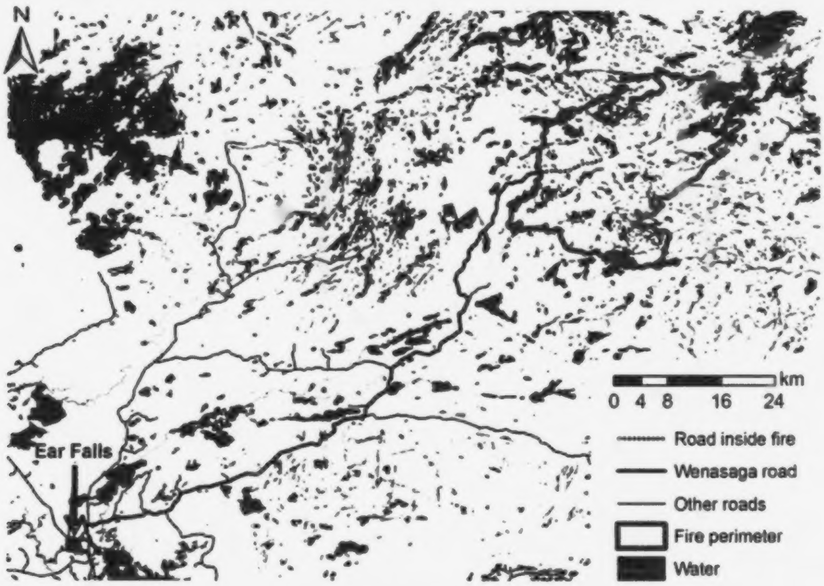


***Figure 45.** Access road from Ear Falls to RED-084.*

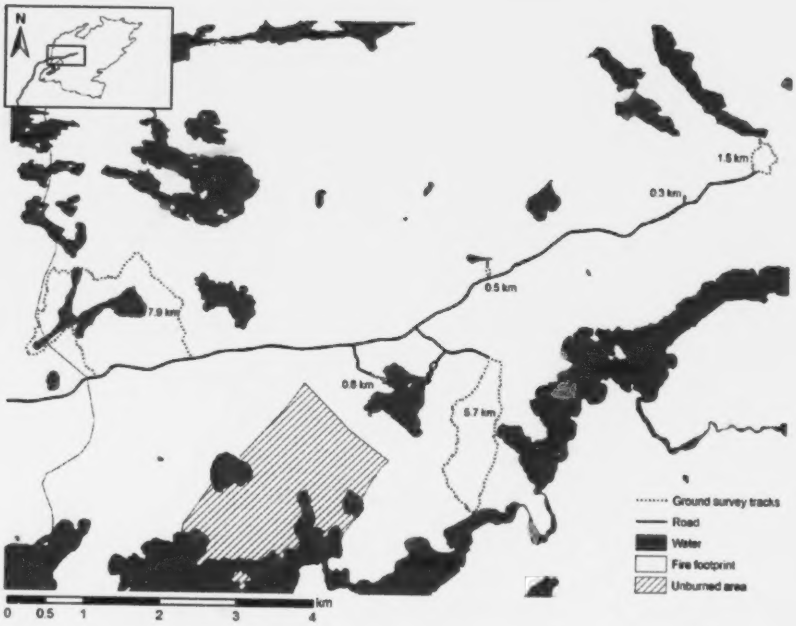


Figure 46. Ground survey tracks within the western part of RED-084.

4.3.1 Pre-burn conditions

Site conditions that indicate the pre-burn characteristics of the burned area were evident throughout, in the residual patches and outside the fire perimeter. The images below indicate the range of conditions we encountered.

***Figure 47.** Dry site with jack pine-dominated stand in an unburned part of the fire.*

***Figure 48.** Undulating rocky and dry site with sparse jack pine trees and lichen ground cover.*

Figure 49. *Moist site dominated by old black spruce in an unburned part of fire.*

Figure 50. *An unburned lake shore within the fire, dominated by black spruce.*

Figure 51. A wet site with sparse black spruce tree cover within the fire.

Figure 52. Thick sphagnum moss ground cover in an old (80-100 years) jack pine-black spruce mixed stand.

4.3.2 Fire behaviour

We observed the results of different fire behaviour patterns within RED-084. Based on the classification of fire intensity classes of the Forestry Canada Fire Danger Group (1992) and degrees of snag fine branch structure destroyed (Smith et al. 2008), we grouped our observations into five categories of fire behaviour types (Table 9).

Table 9. *Classification of fire behaviour types according to fire intensity classes (Forestry Canada Fire Danger Group 1992), the snag fine branch structure destroyed (%) (Smith et al. 2008), and our estimates of ground fuel consumption.*

Fire Type	Fire intensity (kW m^{-1})	Snag fine branch structure destroyed (%)	Ground fuel consumption (Burn severity)
Continuous crown	>4000	>90	Very high (duff consumed to mineral soil layer)
Intermittent crown	2000-4000	10-90	High (ground fuels completely burned and duff layer severely burned)
Surface	500-2000	<10	High to moderate (ground fuels not completely burned and duff layer somewhat burned)
Creeping surface	10-500	0	Low (only ground fuel burned; duff layer not burned)
Smouldering	10<	0	Very low (surface organic layer burned)

Crown fire

Figures 53 and 54 show evidence of continuous crown fire, where all trees have died and all ground fuel has been entirely consumed. Figure 53 illustrates a post-fire condition in a mixed stand of black spruce (90%) and jack pine (10%) of about 18 m tall, with an 8 m crown base height. Due to continuous crown fire, all trees have died with the fine branch structure nearly 100% destroyed and ground-level fuel entirely consumed (Figure 54).

Figure 53. A continuous crown fire in a back spruce-jack pine mixed stand within RED-084.

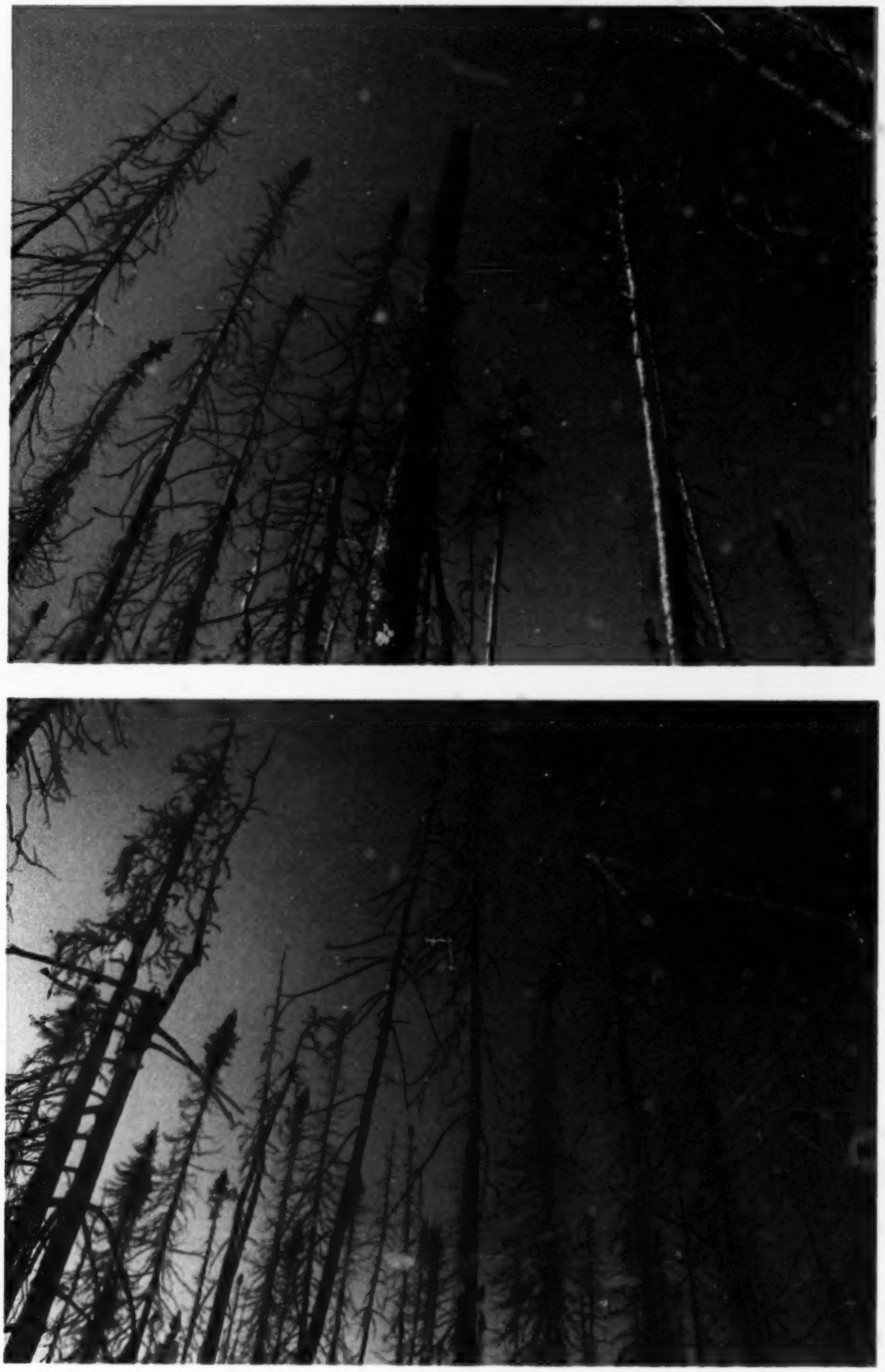


Figure 54. Canopy of a black spruce – jack pine mixed stand after continuous crown fire.

Figure 55 shows evidence of intermittent crown fire. It illustrates the post-fire conditions in a pure black spruce stand of about 15 m tall with 7 m crown base height. Due to the intermittent crown fire, most trees have died, with up to 90% of fine branch structure destroyed and a high level of ground-level fuel consumption.

Figure 55. An intermittent crown fire in a pure black spruce stand within RED-084.

Surface fire

We saw evidence for varying degrees of surface fire – from high intensity (Figures 56) with some crowning to moderate (Figure 57) with no crowning.

Figure 56 shows a mixed stand (90% black spruce, 10% jack pine) with a stand height of 23 m and crown base height of 13 m where <10% fine branches were destroyed. The ground level fuel consumption has been high in this high intensity surface fire.

Figure 56. *High intensity surface fire in a black spruce-jack pine mixed stand.*

Figure 57 shows a mixed stand (90% black spruce, 10% jack pine) with a stand height of 22 m and crown base height of 10 m where no fine branches were destroyed. The ground level fuel consumption was not high in this moderate intensity surface fire.

Figure 57. Moderate intensity surface fire in a black spruce-jack pine mixed stand.

Internal spotting

Isolated burned areas, mostly a few square metres were present within some residual patches (Figures 58 and 59). In some instances it was evident that the spot fire was limited to the surface (Figure 58), and in others the surface fire had reached the crowns from surface, or vice-versa (Figure 59).

Figure 58. *Small patch of a spot fire within a mature black spruce stand, which appears to have been constrained to a surface fire.*

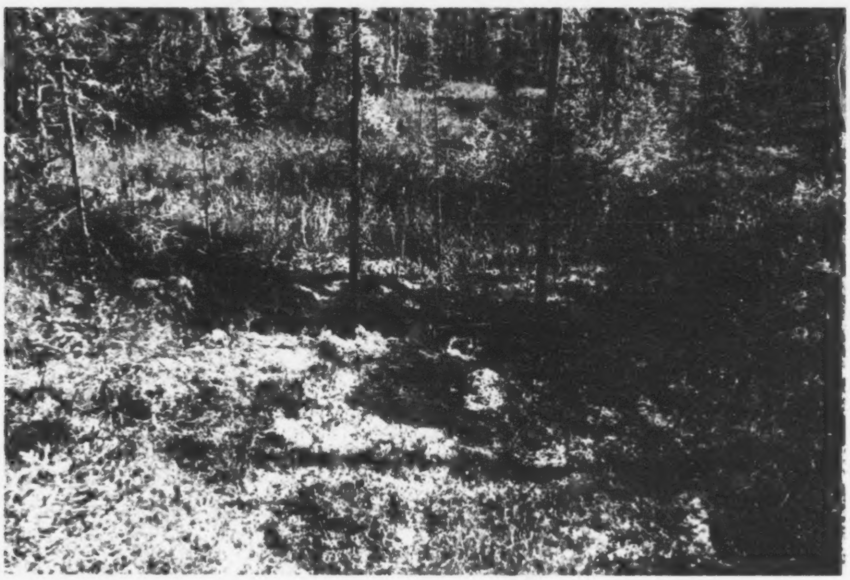


Figure 59. *A small spot fire within a sparse black spruce stand, where some small trees showed evidence of crowning.*

4.3.3 Residuals

We came across many residual patches of various cover types within the perimeter of the fire. There were no signs of fire within these patches, as the fire had completely avoided spreading though them (Figures 60 and 61). Some, for example as shown in Figure 61, are associated with lake shores and wetlands. But this is not always true as many lake shores and relatively wet areas were completely burned (Figure 62).

Figure 60. A mature jack pine-black spruce stand within an unburned patch.

Figure 61. Some lake shores contain unburned areas that escaped fire completely.

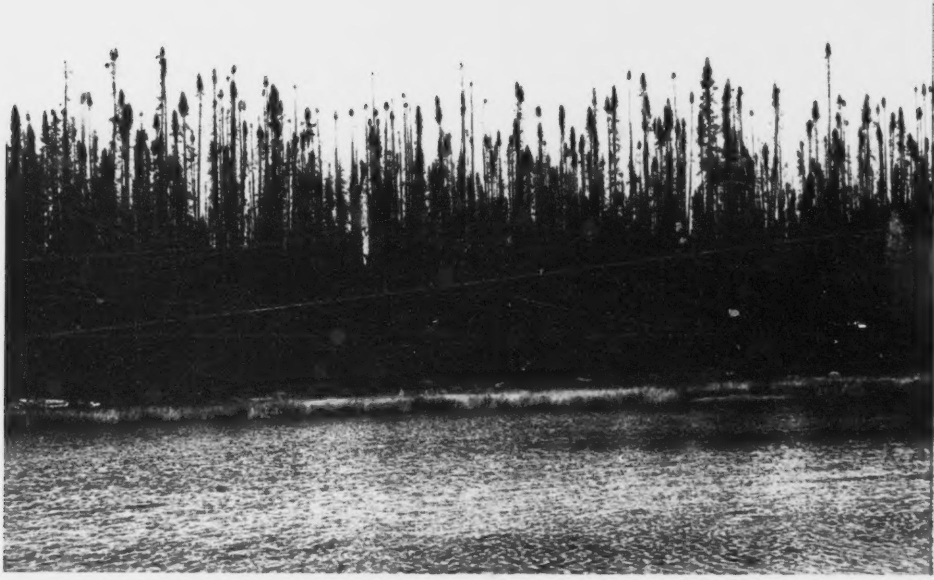


Figure 62. Some lake shores were burned to the edge of the water.

Beyond the residual patches, we rarely encountered live residual trees that occurred individually and had survived or escaped the fire. These were found only at the transitions between burned and unburned areas (Figure 63 and 64).

Figure 63. Transition from burned to unburned area. Most live trees found within the fire were associated with such transitions or occurred in clusters near the edges of large unburned areas.

Figure 64. Live trees were common at the edges of unburned patches.

4.3.4 Blowdown

As seen from the air, RED-084 contained many areas that were affected by blowdown prior to the fire, as evident from lack of signs of fire in some areas (Figure 65). These areas were present near lake shores and other areas typically exposed to wind and had been burned (Figure 66).

Figure 65. Large areas of blowdown were seen within the fire. Some, as the stand above, did not burn.

Figure 66. Blowdown near lake shores were a common sight, and most such areas did not escape fire.

4.3.5 Harvest

The harvested area that we traversed within the fire was completely burned, as the fire had spread through the harvest debris (Figures 67). The post-harvest residual patches and trees were also consumed by the fire (Figure (68), including the lake buffers (Figure 69 and 70).

Figure 67. The harvested area, including all debris, had burned.

Figure 68. Fire had consumed the post-harvest residual trees and patches.

Figure 69. Some post-harvest lake buffers were burned through to the lake shore.

Figure 70. The burned lakeshore buffer area (left during harvest) in the foreground, with an unburned area on the opposite side, surrounded by burned forest in the background.

4.3.6 Animals

Our visit was only 32-33 days after the fire was declared under control and already many signs of animal activities were evident within the burn. Saprophagous bark beetles had already arrived, and their larvae were seen burrowing galleries inside the bark of residual snags (Figures 71) in some parts of the fire. Frass that surrounded the bases of snags indicated the presence of these larvae in the subcortical layers (Figure 72). Though not verified, we suspect these to be beetles that typically feed on phloem and cambium of dead or dying trees, such as species of the family Buprestidae (Figure 73).

Figure 71. *Beetle larvae galleries under the bark of a fire-killed snag.*

Figure 72. *Some snag bases contained frass, indicating the activity of saprophagous beetle larvae.*

Figure 73. *Saprophagous bark beetle larvae were already active in the snags of the fire.*

The birds that prey on such pyrophilous insects, such as woodpeckers (Black-backed *Picoides arcticus*, and Three-toed *Picoides dorsalis*) were also seen in the same vicinity (Figures 74 and 75). Their attempts to feed on bark dwelling insects were evident by scars on the bark of snags (Figure 76). Other predatory birds observed in RED-084 included Northern Shrike (*Lanius excubitor*) and Northern Hawk Owl (*Surnia ulula)* (Figures 77 and 78).

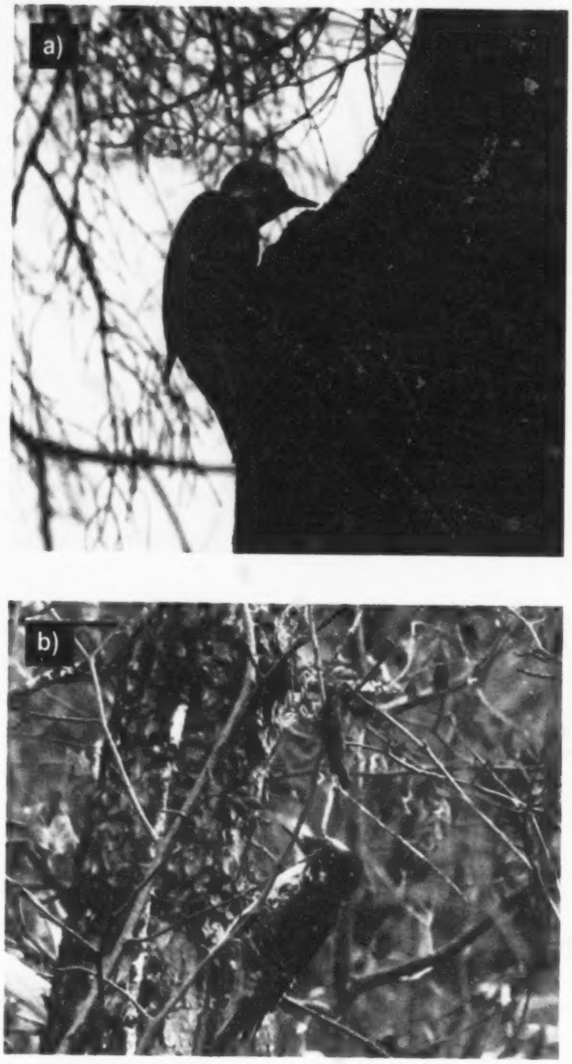


Figure 74. *Woodpeckers found in the fire: (a) Black-backed and (b)Three-toed.*

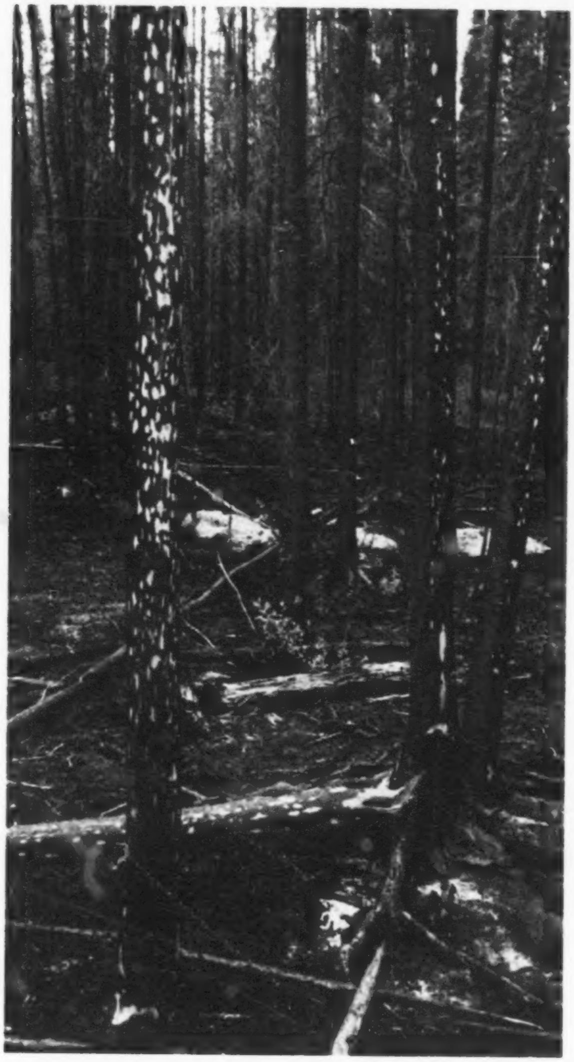


Figure 75. *Post-fire snags pecked by woodpeckers in search of bark beetles.*

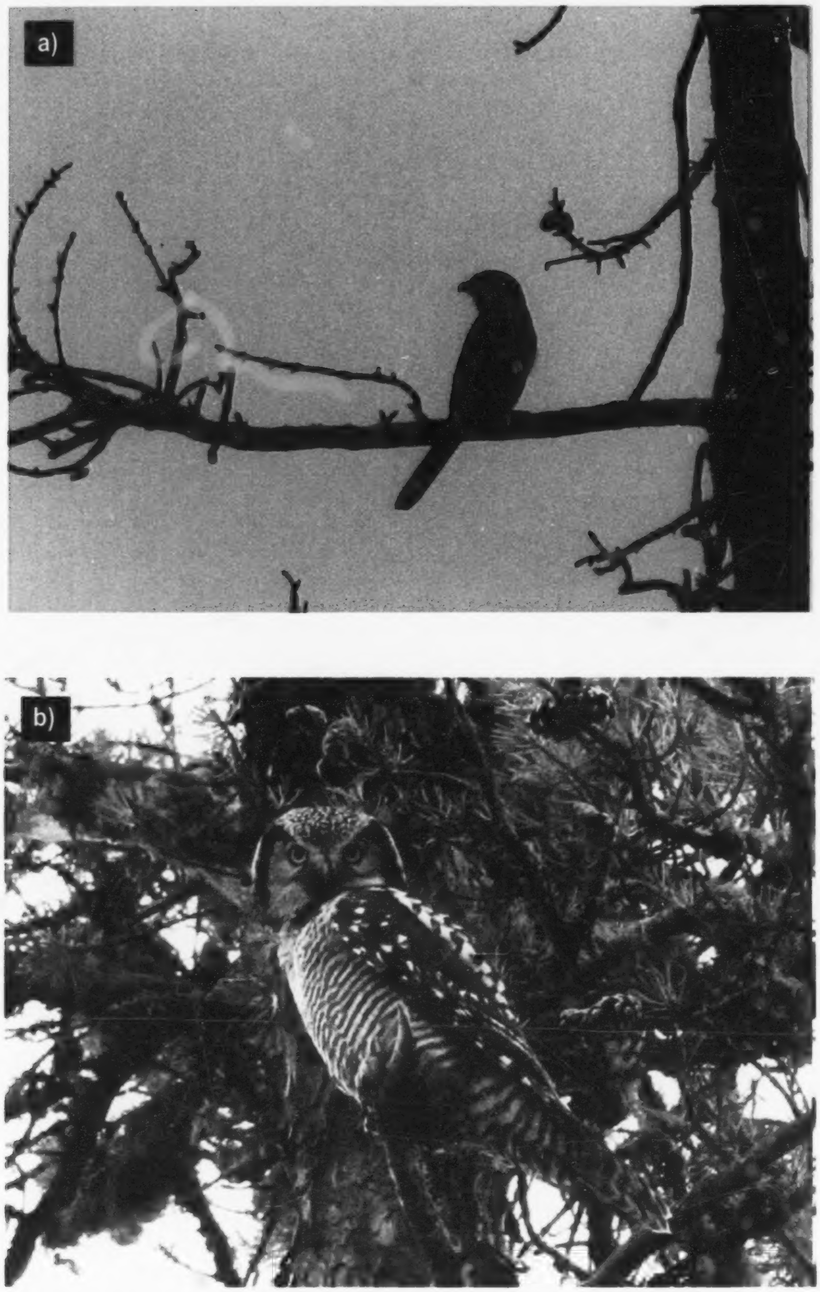


***Figure 76.** Other predator birds seen in the fire: (a) Northern Shrike, (b) Northern Hawk Owl.*

4.3.7 Regeneration

Serotiny of jack pine, where the mature cones open when exposed to high temperatures within forest fires was apparent within the fire (Figures 77).

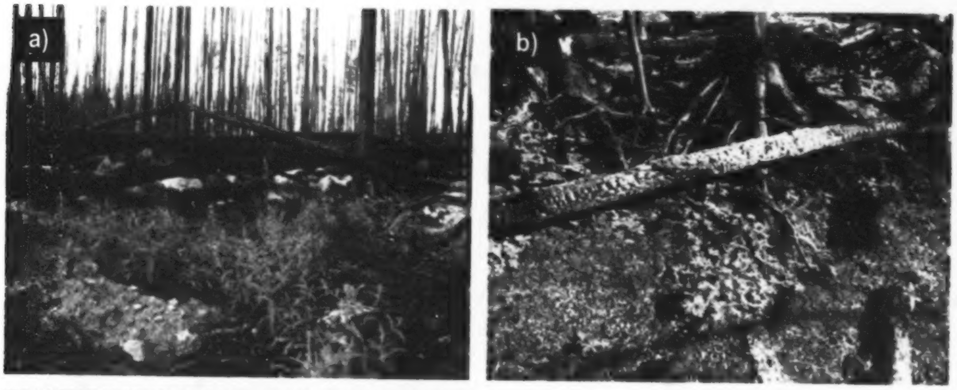
Figure 77. Scorched jack pine crown with serotinous cones.

After severe surface fire, the forest floor becomes more favourable for germination and re-establishment of some boreal tree species. Within couple of months of the fire, jack pine seedlings have already germinated (Figure 78).

Figure 78. Newly emergent jack pine seedlings on the burned mineral soil.

Other tree species such as trembling aspen (*Populus tremuloides*) and white birch (*Betula papyrifera)* that resort to sprouting from unburned parts such as roots and stem have also started the regeneration process (Figure 79). Other species have also begun the recolonization process, even in areas of high fire intensity. These included species of fireweed, geranium, and horsetail (Figure 80).

Figure 79. *Regeneration from sprouts within a month of the fire: (a) trembling aspen and (b) white birch*



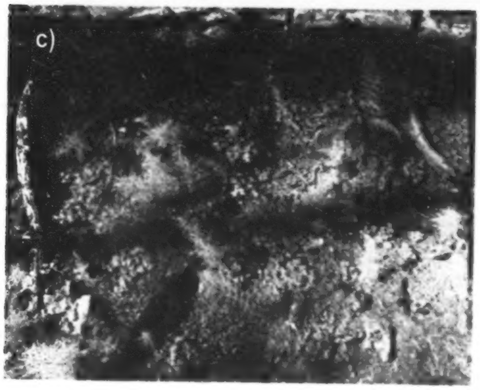


Figure 80. *Emergence of understory plants immediately post-fire: (a) fireweed (b) geranium (c) horsetail.*

5.0 Concluding Remarks

Our observations, both during and after the fire event, by air and on the ground, would be overlooked if not documented. This documentation, while being qualitative and subjective, enables us to provide valuable insight about the fire's spread and progression, as well as post-fire spatial patterns. RED-084 is an uncommonly large wildfire, even for a highly fire-prone boreal forest landscape. Furthermore, it meets most criteria, such as undisturbed pre-burn landscape, lightning-caused ignition, and little effect from fire suppression efforts, of a 'natural' fire. As such, this fire event provides many opportunities for studies that could advance the understanding of patterns and processes associated with boreal wildfires. These topics could range, for example, from mapping techniques, quantifying patterns at various scales, spatial signatures of fire behaviour, post-fire residual characteristics, ecosystem recovery process from a stand-replacing disturbance – including plant and animal succession as well as abiotic cycles – to interactions among disturbances, such as harvest-fire and blowdown-fire. We anticipate this compilation of details of the fire event and observation of the immediate post-fire landscape to provide some baseline information for such future studies.

6.0 References

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Appendix A - Air survey

Following are details of the aerial reconnaissance survey of RED-084 on October 04, 2011 that supplements Section 4.2.This survey was conducted by fixed-wing aircraft, at an altitude of 600 m, following the flight path illustrated in Figure A0.

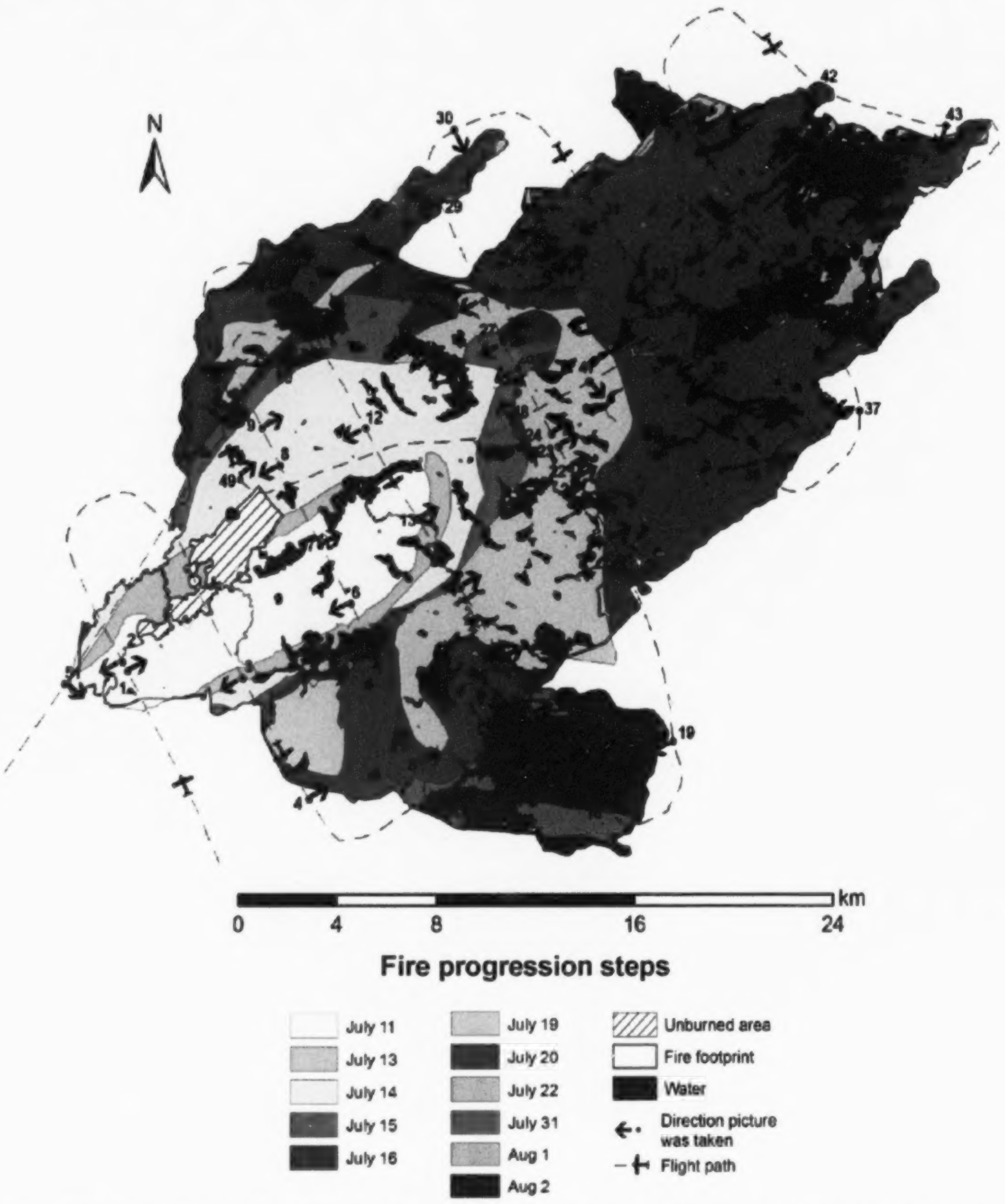

Figure A0. *Flight path of the aerial survey of RED-084, including the approximate locations of the photographic images.*

Figure A1: *Southwestern corner of the fire, near the point of ignition. It shows the power transmission line that crosses southern part of the fire footprint.*

Figure A2: *Southwestern corner of the fire near Wenasaga River and Allisa Lake, showing the fire edge caused by the backfire and the unburned area outside the fire perimeter.*

Figure A3: *Spotfire at the southwestern edge of the fire perimeter, west of Tarpley Lake.*

Figure A4: *Spot fires near the southern edge of the fire perimeter, south of St. Roy Lake.*

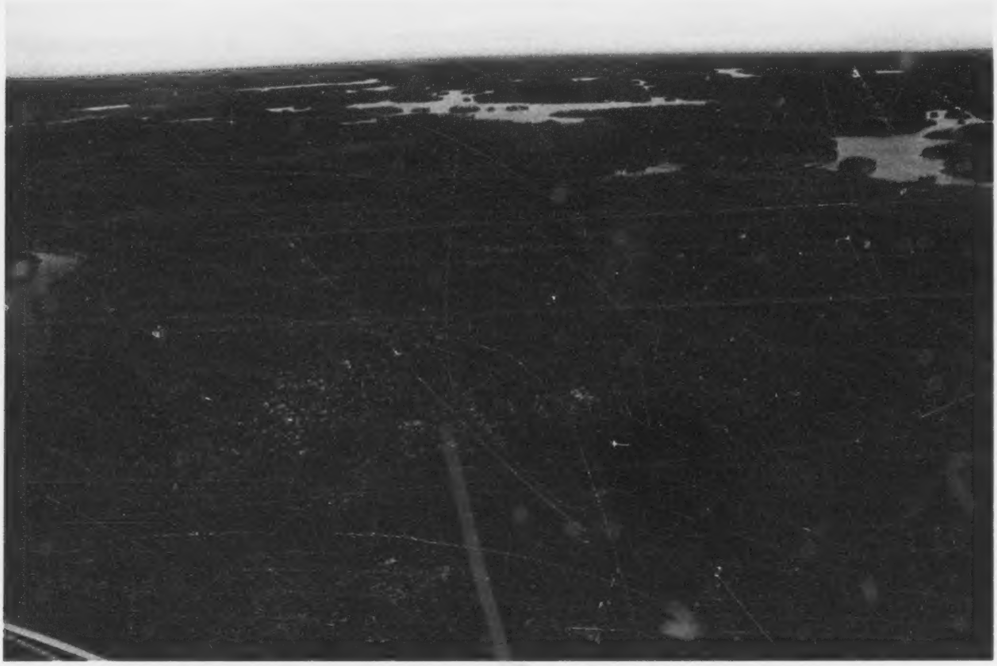

Figure A5: *Southern part of the fire with evidence of high severity burn interspersed with residual patches. This area burned on Day 10.*

Figure A6: *Centre of the fire, in the area burned during the second day of the burn, with evidence of high severity crown fire.*

***Figure A7:** Centre of the fire, looking towards Marsh Lake in the direction of fire spread, indicating high severity burn during Day 2.*

***Figure A8:** Harvested area in the western part of the fire. Fire had swept through the post-harvest debris and some forest patches and trees were left behind.*

Figure A9: *Burn pattern well inside the northwestern edge of the fire, in the area that burned during Day 5.*

Figure A10: *Looking towards Bumpy Lake in the northwestern flank of the fire, burned during Day 9. Lake edges burned with little evidence of impedance of fire spread.*

Figure A11: *A peninsula of Bertha Lake which was completely burned, consuming the forest cover along the lakeshore.*

Figure A12: *The logging road that extends towards the centre of the fire, with patches of high severity fire and large unburned patches.*

Figure A13: *Heterogeneity in burn severity, with several low-lying areas that escaped the burn. These unburned areas conform to the O1-b fuel type on the pre-burn fuel classification map. Lakeshore in the foreground is partially burned, with evidence of blowdown.*

Figure A14: *An area of high severity burn with evidence of intermittent and continuous crown fire.*

Figure A15: A peninsula of the Sesikinaga Lake complex with areas of partial burn and complete burn along the lakeshore.

Figure A16: Moderately severe burned area in the southern part of the fire, which happened during the last days (July 31-August 02).

Figure A17: *Southern part of the fire between Jeanette and Sesikinaga lakes, burned during the last day (August 02).*

Figure A18: *Southernmost edge of the fire, with area of high severity burn. The area outside the fire perimeter is in the background.*

Figure A19: Southern fire perimeter by Sesikinaga Lake. High severity burn patches are surrounded by large unburned areas.

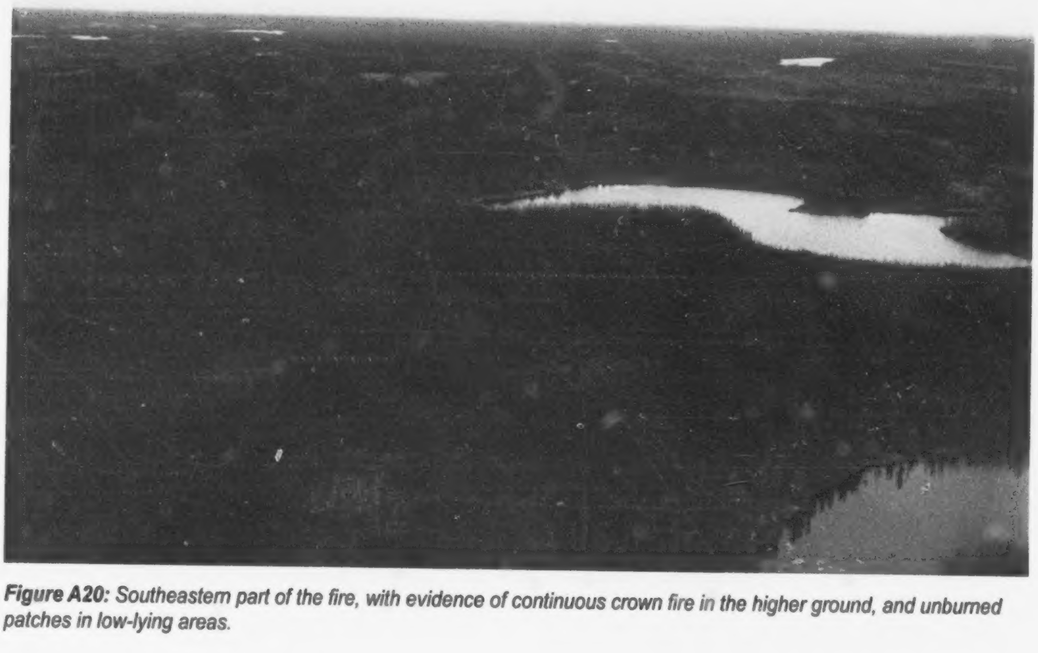

Figure A20: Southeastern part of the fire, with evidence of continuous crown fire in the higher ground, and unburned patches in low-lying areas.

***Figure A21:** High severity burn in the background, and a mosaic of smaller burn patches near the centre of the fire.*

***Figure A22:** Mosaic of burned patches near the centre of the fire. A mixture of burned, unburned, and blowdown areas are visible around the lakeshore.*

Figure A23: *A high severity burn patch in the central part of the fire juxtaposed with a burned lakeshore and an unburned lowland.*

Figure A24: *High heterogeneity in burn pattern in the centre of the fire. Evidence of partial ground fuel consumption with crown scorching is seen in the foreground.*

Figure A25: *Interspersion of burned and unburned patches. Deaddog Lake in the centre of the fire is visible in the background.*

Figure A26: *Moderately severe burn patches in the area of the 1999 fire. The sparse tree cover may be due to the effect of that fire.*

Figure A27: In the vicinity of the 1999 burn. Some areas appear to have eluded both fires.

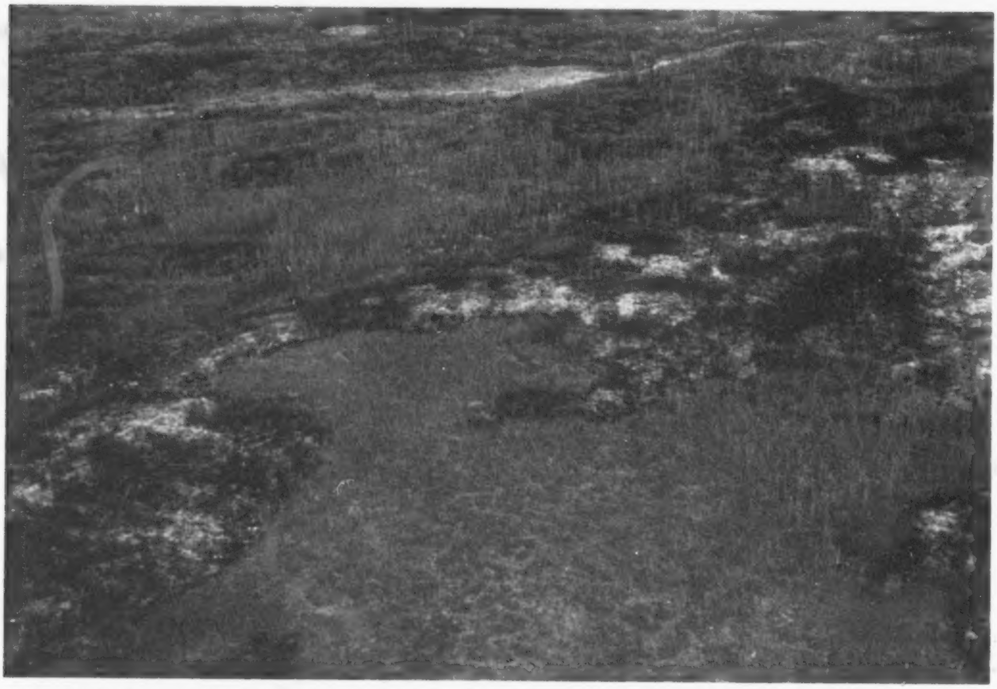

Figure A28: Patches of high intensity surface fire that border low-lying ground in the area of 1999 burn.

Figure A29: *A lake peninsula in the northern part of the fire, burned by intermittent crown fire, including the shores.*

Figure A30: *Northern edge of the fire, with few burned areas visible in a matrix of lakes and unburned forest landscape.*

Figure A31: High severity burn area near Seagrave Lake. This area had the fastest fire spread, nearly 18 km in one day (July 20).

Figure A32: A lake in the middle of the area of fastest fire spread. The continuous and intermittent crown fire had consumed all but a small area of the lakeshore.

***Figure A33:** High severity burn in the north central part of the fire with fastest fire spread. Continuous crown fire is evident throughout.*

***Figure A34:** A large unburned area, both low-lying and higher ground, in the middle of the area of fastest fire spread. The wetland area conforms to the M-2 fuel type on the pre-burn fuel classification map.*

Figure A35: Mosaic of severely burned forest and unburned low-lying areas and lakeshores in the centre of the fire where fire spread was most rapid.

Figure A36: Intense fire activity at the eastern flank of the fire edge, near Deaddog Creek. Background is outside the fire perimeter.

Figure A37: *Eastern edge of the fire, looking towards the fire. Spotting had burned the island, in the direction of fire spread.*

Figure A38: *Eastern part of the fire, with Christina Lake in the background. Fire seemed to stop at low-lying areas.*

Figure A39: Northeastern part of the fire, where fire spread was fast. Some low-lying areas escaped fire.

Figure A40: All lakeshores were burned with no unburned forest cover in this area in the northeastern part of the fire.

Figure A41: *Sporadic patches of burn at the northern edge of the fire had been dormant for over 10 days before spreading again on August 01.*

Figure A42: *At the northeastern edge of the fire perimeter near Gull Lake, looking towards the fire.*

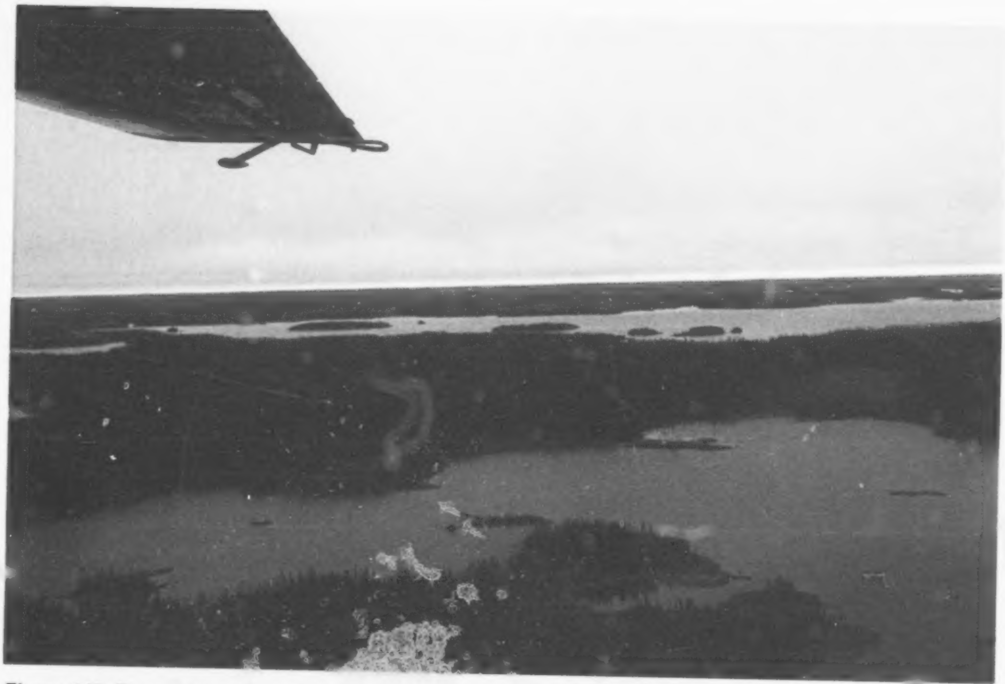

Figure A43: *The very (northeast) end of the fire. There was no evidence of fire spread beyond this part of Gull Lake.*

Figure A44: *Gull Lake shore inside the fire perimeter. Most lakeshores were burned by crown fire in this area.*

Figure A45: *Evidence of large areas of continuous crown fire in the middle of the area of most rapid fire spread.*

Figure A46: *Presence of large unburned areas, including lakeshores in the centre of the area of most rapid fire spread.*

__Figure A47:__ In some parts in the centre of the fire, water bodies appear to have stopped fire progression as evident by the unburned forest cover in the background.

__Figure A48:__ Large unburned areas in the centre of the fire, where fire had progressed slowly (July 16).

***Figure A49:** Another view of the harvested area within the fire perimeter.*

***Figure A50:** An unburned outpost camp on Ruddy Lake within the fire. Evidence of fire is present around the building and other areas. According to fire staff blowdown along the lakeshore was a result of intense ground fire burning the root systems.*

Figure A51: The end of the southwestern edge of the fire perimeter.

Appendix B – Ground Survey

Following are details of our observations from one ground survey track (Figure B0) , conducted on October 06, 2011. This information supplements Section 4.3.

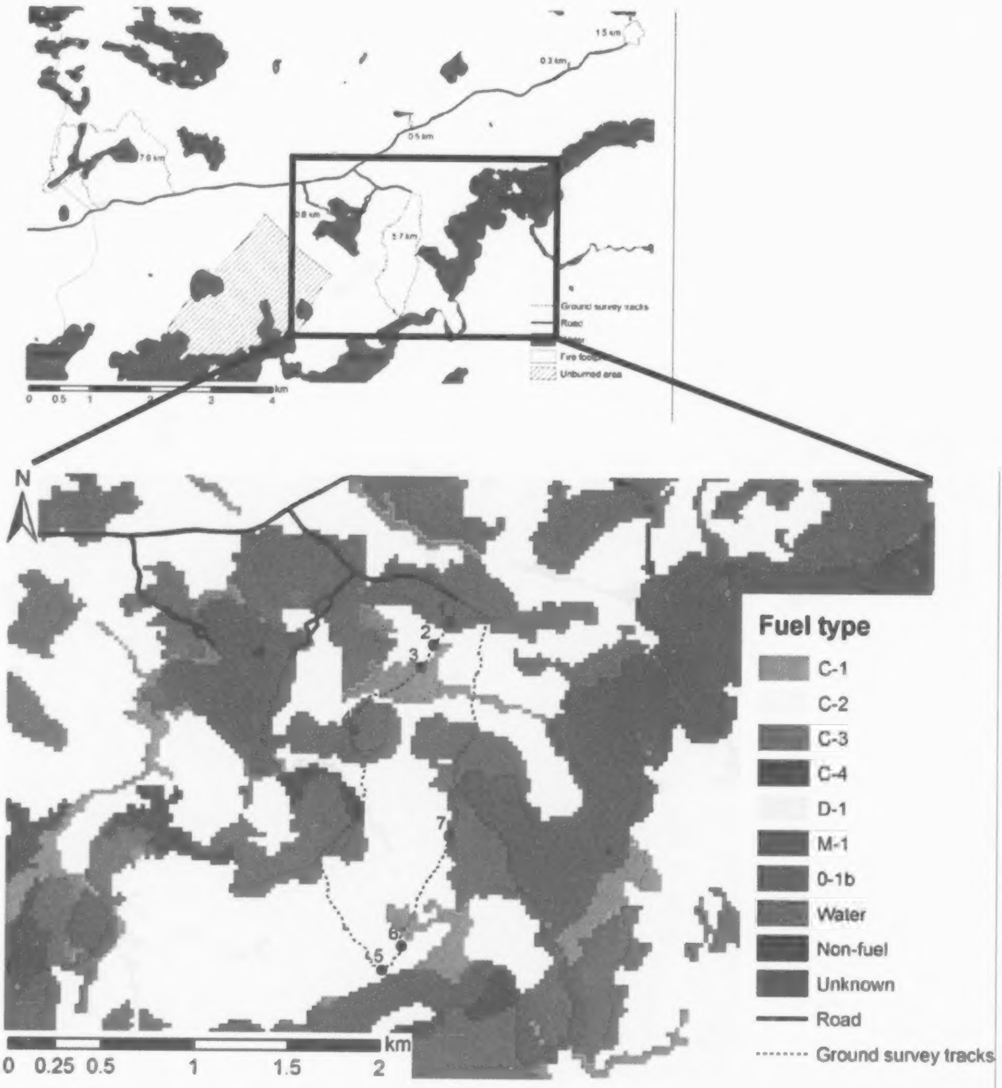

__Figure B0.__ The ground survey track (its location indicated in the inset) used for collecting images (locations 1-7) and information described in this appendix, with the pre-burn fuel type distribution in RED-084.

Figure B1.1: *Dominant pre-burn cover was 85-year-old black spruce with an average height of 14 m and an average crown base height of 5 m.*

Figure B1.2: *A view of the ground condition and C-3 fuel type. The intensity had been low in this surface fire, with <1 m flames scorch height. Over 90% of the trees were alive.*

Figure B2.1: A 120-year-old upland black spruce stand with an average height of 19 m and an average crown base height of 8 m.

Figure B2.2: A view of the ground condition and C-2 fuel type. There was no evidence of burn in this area.

***Figure B3.1**: Dominant pre-burn cover was 160-year-old lowland black spruce, with an average height of 10 m and an average crown base height of 4 m. Most crowns were scorched due to low crown base height, and appeared to be dead.*

***Figure B3.2:** A view of the ground condition in the burned C-1 fuel type. Evidence suggested that the surface fire had been intense.*

Figure B4.1: *Dominant pre-burn cover was a mixture of 70-year-old black spruce (90%) and jack pine (10%) with an average height of 18 m and an average crown base height of 7 m.*

Figure B4.2: *Evidence suggests that this area had a high intensity surface fire in the C-3 fuel type. Most trees appeared to be live, with <10% fine branch structure destroyed. The incidence of tree fall was high, with most*

Figure B5.1: *Dominant pre-burn cover was a mixture of 60-year-old black spruce (80%) and balsam fir (20%) with an average height of 20 m and an average crown base height of 6 m. The fire had burned to the shoreline of the lake.*

Figure B5.2: *Pre-burn fuel type was C-2. The condition here indicates a very high intensity ground fire, which climbed the stems and consumed the crowns of most trees.*

Figure B6.1: Dominant pre-burn cover was 60-year-old upland black spruce with an average height of 17 m and an average crown base height of 6 m. All trees have died due to high intensity crown fire in the C-2 fuel type.

Figure B6.2: The ground fuel consumption was very high, as evident from the exposure of tree roots.

Figure B6.3: *High level of crown fuel consumption is evident, with the loss of all fine branches.*

Figure B71: *Dominant pre-burn cover was a mixture of 55-year-old black spruce (80%) and jack pine (20%) with an average height of 17 m and an average crown base height of 6 m. Many old snags and downed wood had been present prior to the fire. It is apparent that a high intensity crown fire occurred in this C-3 fuel type*

Figure B7.2: *The ground fuel consumption here was very high, as evident from the exposure of tree roots. All surface fuel and the humus layer were consumed leaving the mineral soil.*

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